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Early Fertilization

The importance of early fertilization is being realized more and more throughout the world. The Louisiana sugar planters, with their heavy rainfall, are now turning to early fertilization with nitrate of soda in addition to acid phosphate. This is a change from cottonseed meal and tankage. Dr. Schurig-Markee, a leading German agriculturist, recommends the application of nitrogenous fertilizers "as early as possible, and in one application instead of several." Of course this is for shorter crops than ours in Hawaii.

A Discussion of the Root Rot Problem*

By W. T. McGeorge

Certain phases of the investigations being conducted on the root rot problem, which appear to be pertinent to our own local problems and a short discussion of the results which we have obtained in the researches being conducted at the Sugar Planters' Experiment Station, are herewith presented. To begin with, there is more or less confusion in the use of the term root rot. In sugar cane it is an outgrowth of the older term Lahaina disease. We would anticipate the association of the retarded root development in most cases of plant failure from a number of influences, and such occur in practice. It has been generally assumed that it is safe to attribute the retarded development of the plant as a whole as secondary to root failure. This assumption has been the incentive for many years of search of the bacterial and fungi flora of our soils for causal organisms. As you may know, failure in this line of investigation is widely admitted, although there are not lacking a number who still cling to the strictly pathological phase of root rot. What I mean to infer by the above is that the too general application of the term root rot is unfair.

* Presented at meeting of Hawaiian Section of American Chemical Society, Honolulu, November 1, 1924.

Rapid strides in the progress of methods of soil research during the last ten years have provided or armed us with better methods or weapons of attack for such problems. As related to investigations in plant failure the progress of soil and physiological chemists in the study of soil toxins and plant nutrition should be mentioned. The more accurate methods of measuring soil reaction and a method for removing the soil solution for study are of interest.

Before proceeding further it may be best to briefly review our local problem. A casual survey of the Island districts in which Lahaina cane failed and where conditions diagnosed as root rot prevail shows a startling variety of soil types of equally varying properties, mostly abnormal. To mention a few of these, the acid soils of the Hilo-Olaa and Hamakua districts deficient in potash and high in ferrous iron and organic matter; some alkaline soils on Maui; on Oahu the Kaneohe soils of high acidity, high in soluble iron aluminum and manganese salts and deficient in both potash and phosphate; the lower fields of Ewa-Puuloa district, which are alkaline or nearly neutral; the mauka fields on Kauai and other upland areas which are similar in many ways to those at Kaneohe.

The description of the condition of plants as observed by various members of the station staff also shows some variation.

While fungi or other organisms have always been found, by the pathologists, present in the rotted roots, the discovery of a primary causal fungus has not been effected in spite of many intensive investigations. Dr. Lyon, as early as 1915, stated that we may eliminate senility and parasitic organisms as a plausible explanation for Lahaina disease. In view of this I will therefore omit a review of the pathological phase of root rot studies made in the Islands.

It is obvious from past observations that we are led to assume the association of the ever present fungi as a secondary factor only, and that some other agent resident in the soil is the primary cause. I think that I may safely say that the principal mistakes and failures of the past have been due to the apparent assumptions that root rot is the result of a single causal agent in all cases rather than a general problem involving a number of phases of soil infertility. At least it is true that the most promising results in Europe and on the mainland have been obtained and the greatest progress made by the investigators who have treated the problem as a complex.

In our own soils several possible primary chemical, physical and bacteriological factors suggest themselves and all have been found to be definitely associated with soil infertility.

1. Climatic conditions, such as rainfall and temperature, not within the range of adaptation of the plant or variety. For example, H 109 is totally unsuited to many Island localities, yet we hear no mention of H 109 disease.

2. Poor physical condition of the soil which inhibits proper aeration for root respiration.

3. The presence of soluble substances in the soil solution which are toxic toward plant growth. These include many organic and inorganic compounds of known toxicity.

4. Conditions productive of abnormal or subnormal activity of soil microorganisms.

5. Plant food deficiencies or excess, more especially the former at certain critical periods in the development of the plant. This would include nutritional disturbances or abnormally balanced nutrients.

The Chemical department of the Experiment Station has, during the last several years, reopened the root rot problem and treated it along the lines suggested by a knowledge of our soil types and on the basis of several lines of investigation being intensively pursued in Europe and on the mainland. The results thus far have yielded some extremely illuminating data. Our studies to date have been confined almost entirely to acid soils so that this discussion will be limited to them.

During the last summer I had the opportunity of visiting a number of agricultural institutions on the mainland and comparing the progress of our work with theirs. The similarity of our observations was amazing and I will discuss some of these in detail.

At the Indiana Experiment Station, Dr. G. N. Hoffer, specialist in plant physiology and pathology, is studying the problem. He is probably the leading investigator on the problem of aluminum toxicity, a factor which has been shown to be definitely associated with corn root rot in the Middle West as the primary causal agent. It is significant in his work that he avoids being led into single channels of investigation through the discovery of dominant factors. That is, he continually keeps in mind all possible associated factors which are present and which may contribute to plant failure. It is also significant that in spite of the fact that he is a pathologist and has given careful attention to the fungi flora of the decayed roots he has found chemical factors playing the primary role. In other words, he has not succeeded in producing root rot in a properly nourished plant by inoculation with any of the contributing organisms. A few words regarding his theories and methods of study are of interest.

He divides plant growth into three zones: health, susceptibility and toxicity. The zone of health is defined as the environment conducive of optimum plant growth; that of toxicity as having sufficient concentration of toxin or other inhibiting factor to seriously or completely inhibit plant growth of itself. Within the zone of susceptibility we have an environment productive of sufficient loss of plant vitality to predispose the plant to the invasion of organisms. Within this zone we have only subtoxic concentrations of toxins and plant food deficiencies as factors which lower plant resistance, and within this zone most problems in soil fertility arise.

Root rot in the toxic zone makes its appearance in the young plants, the concentration of toxic agent being sufficient to entirely retard even subnormal development.

In this connection, while Whitney and Cameron's original suggestion that plant roots secrete toxins is not considered entirely correct, on the other hand it has been shown that while healthy roots secrete CO_2 only, if the oxygen supply is limited by poor aeration the roots will secrete organic acids. These acids could act as solvents for aluminum producing aluminum toxicity in immediate contact with the roots even in an alkaline soil.

Within the zone of susceptibility his theory as to plant failure in corn attributes root rot to be secondary to notable disturbances which he has discovered in the stalk. He finds that growth retarding factors induce accumulations of iron

and aluminum at the nodal joints. There results a discoloration of the vascular plate tissues and a certain degree of disintegration. Dr. Hoffer believes that this nodal accumulation precedes the rotting of the roots, the channels of food transmission within the plant being disrupted. There results also increased enzymatic activities in the plant juice, a setting of the protoplasm and other abnormal conditions. Thus aluminum and iron become inhibiting growth factors even in the absence of appreciable solubility in the soil solution. To further explain Hoffer's theory, he has shown by experiment that where retarded growth is induced by a deficiency of potash or phosphate the vitality is lowered sufficiently to permit the fungi invasion.

In sugar cane we find these same nodal accumulations of iron and aluminum regardless of their solubility in the soil. Wherever the stalk is stunted, whether on acid soils, soils of high saline concentration, or even on the short winter growth of the stalks these elements accumulate.

Independent of Hoffer, Bodnar at the Royal Hungarian Institute of Plant Physiology also found a predisposition of the plant tissues to fungus invasion in the presence of high aluminum absorption. His problem was the root rot of sugar beet. As one phase of his investigation he analyzed normal beets, badly rotted beets and partially rotted beets. In the latter he analyzed the healthy and affected parts separately. The principal difference in the composition of the ash was the greater aluminum content of the rotted bulbs. (Diseased beets 6.8-10.2 per cent and healthy beets 1.28-2.57 per cent.) Also, he found the aluminum content of the diseased portion of a single beet to be higher in aluminum than the healthy portion. One of the conclusions reached in his work was that the increase in aluminum content of the beet precedes the invasion of the organism and predisposes the tissues.

Having shown the presence of soluble iron, aluminum and manganese in the Island soils, our initial studies involved the identification of the types in which the salts of these elements are actually present in the soil solution. A method for determining the so-called active aluminum has been published by the Rhode Island Experiment Station. We have, however, adopted a different and, I think, a better procedure and have determined the range of H ion concentration at which it is possible to have these salts present in the soil solution. This investigation showed that all soils of H ion concentration greater than that represented by pH 5.8 fall in this class. Above this pH we must search for other factors where root rot is present. Many of our soils have pH below 5.8 and root rot is prevalent in many such fields. This higher acidity is typical of upland soils and includes a large percentage of the pineapple as well as many of the sugar lands.

Now as for the toxicity of the salts of the elements iron, aluminum and manganese toward sugar cane we have carried out several hundred cultural experiments which have included several of the salts of these elements and of the representative varieties of sugar cane. It will be impossible to more than touch upon these experiments. Suffice it to say that aluminum salts showed a marked toxicity toward sugar cane, with less resistance in the Lahaina variety.

As for methods of correcting aluminum toxicity in soils there are several possible. These include the precipitation of aluminum in an insoluble form; for example, the phosphate by additions of superphosphate, or by changing the soil

reaction by such neutralizing agents as lime or molasses ash. Our field experiments have not progressed sufficiently to warrant comment. On the other hand, in pot experiments using acid Island soils notable response and remarkable root stimulation has been obtained. These experiments showed that phosphate applications give only temporary response due to the high potential aluminum content of our soils and the fact that the reaction of the soil is not changed by the phosphate application. In our experiments an application of 20 tons superphosphate per acre was completely inactivated in four months time and the original toxicity of the soil had returned. The practical reclamation of such soil types must therefore necessarily involve the use of some neutralizer as a corrective agent; the use of lime has, however, not given immediate response, but this is more or less to be expected. Acid soils of the reaction, at which we find aluminum showing toxicity, are notable for the presence of numerous growth retarding agents. Subnormal bacterial activity, which is characteristic of unfavorable growth media may be mentioned. Also, the poor physical condition and notable plant food deficiencies which are characteristic of these acid types. Organic decomposition in acid soils is notably productive of organic and inorganic compounds unfavorable to plant growth. It is evident therefore that the correction of aluminum toxicity may be only one factor. In Indiana, it is the practice to add 3-4 tons lime per acre plus 500-1000 lbs. superphosphate and then plant to a resistant crop before going to corn. Dr. Conner of the Indiana station, who has had practically twenty years experience with such soil types, in a discussion of the action of lime has the following to say: "We have never been able to grow a normal corn crop on this soil, even with limestone applications up to 14 tons per acre until after a lapse of three years. It is quite possible that aluminum hydrate remains toxic until it is gradually fixed as a single or double silicate or phosphate or as a more insoluble hydroxide. At any rate plenty of available phosphate or silicate hastens the improvement in fertility and crop producing power."

I was much interested at the last pineapple short course at the University of Hawaii to hear statements by two men of wide experience in pineapple culture that liming in the long run had shown some improvement in fertility. A significant case which came to our own attention recently also is of interest. Two samples of soil submitted to our laboratory for examination from Koloa Plantation represented a field which was of poor fertility and a section of this same field which had formerly been a road and on which the cane was making very good growth. The soil was a typical upland soil of high acidity and low in available potash and phosphate. The reaction of the field in general was pH 4.6 and of the former road pH 6.0. Dr. Hoffer has noted a similar situation in an Indiana corn field. The reaction of a field showing root rot had a pH 5.6. In another part of this same field where the corn showed no root rot the reaction was pH 6.2. There is a warning in the above instances against too hasty conclusions from liming experiments. There are too many possible inhibiting factors present in acid soils which may only be corrected in full over extended periods.

During the past summer I saw on the mainland experimental plots which had been receiving ammonium sulphate (without lime) for a period of fifteen years and had reached a condition in which few crops would grow. The only difference between these plots and the check plots was the higher acidity of the

ammonium sulphate plots and the presence of soluble aluminum. When we start liming acid soils, that is, the naturally acid types, let us not forget that those soils have been acid probably for thousands of years and their reclamation may involve unforeseen complexities requiring patience and careful study.

Returning to Dr. Hoffer's zoning of plant growth, let us apply his line of reasoning to some past experiments on the root rot of Lahaina cane. In 1915, Dr. Lyon transferred a sick stool of Lahaina to our Experiment Station soil (which has never shown root rot) and obtained a complete recovery of the stool. In making this transfer he carried the secondary factor (the fungus) into the good soil in which the primary factor was lacking. In the absence of the primary factor the plant recovered on failure of the fungus or secondary factor to play its role effectively in the absence of the primary predisposing agent. This experiment has been repeated recently by Mr. Lee, who transferred "sick" Lahaina stools from Puunene to the Station soil with the same results. This same line of reasoning clarifies some of Carpenter's observations. On sterilizing sick soils he obtained some improvement in plant growth, having removed the secondary factor, the primary factor being present only in subtoxic concentrations. On reinoculating the sterilized soil with pythium type fungus, thereby again reproducing the association of primary and secondary factors, he again produced the root rot.

The outstanding feature of these root rot problems is the comparative resistance of varieties and individual plants. For example, going into a pineapple field one is immediately struck by the apparently normal growth being made by some plants, yet entirely surrounded by wilted plants. The same is true, only less strikingly so, of sugar cane. We see a heavy stand of H 109 where Lahaina scarcely goes beyond the germination stage. The question arises what is the inherent characteristic of these resistant varieties or plants which imparts this power of resistance and can it be determined? We are analyzing many plants grown in our pot cultures which we hope may throw some light on the chemical phase of this question.

Dr. Hoffer has found that there is a definite relation between the phosphate requirement and degree of resistance to aluminum toxicity. That is to say, a plant or variety having a high phosphate requirement will develop root rot more rapidly in the presence of a deficiency, and a phosphate deficiency has been shown to be related to aluminum toxicity and is usually a characteristic of acid soils. Therefore the variety with lowest phosphate requirements shows the greatest degree of resistance. He has even developed this phase of his investigations to such a degree that he can determine the resistance of a seedling by chemical analysis and is using this extensively in breeding corn varieties for resistant strains. He is also studying the selective absorption of iron and aluminum as a heritable character in corn.

Another interesting angle on root rot resistant characters has been uncovered at the Rhode Island station. They find that crops to which aluminum is toxic show a wide variation in mineral composition when grown under different conditions. For example, the carrot shows little variation in mineral composition regardless of environment under which it is grown and is highly resistant. In other words, the ability of the plant to obtain its needs under adverse conditions;

that is, to select its likes and reject its dislikes is a notable resistant character. It is not unfair to assume just some such relation as this in comparing H 109 and Lahaina on high saline concentrations, the H 109 having the greater power of selection.

Again, potash has been found to be an important factor and possesses an essential function in relative resistance. Sherwin, in North Carolina, working on a non-productive soil of pH 3.5 to 5.0, found heavy nodal accumulations in corn, which was suffering from root rot on this soil. Unlike previous experiments on such acid soils this soil did not respond to phosphate applications, but did respond notably to potash and lime. Hoffer, cooperating in these experiments, discovered the function of the potash. He found that potash possesses the property of greatly decreasing or entirely eliminating the nodal accumulations of iron and aluminum. Its action is within the plant. I might add at this point that in our pot experiments we obtained similar results, namely, that by increasing the potash reserve in the plant there was a marked stimulation in plant growth in spite of the fact that the aluminum content and solubility in the soil had not been altered. If a toxin can be cared for within the plant as rapidly as it enters, then the plant is not injured. Dr. Hoffer has further noted a remarkable difference in the appearance of plants in which phosphate and potash separately are limiting factors. In other words we might say that two distinct types of root rot have been described by Hoffer, depending on the nature of the deficiency which is associated with the aluminum. How many more distinct types there are can only be conjectured.

In closing, the point which I wish to emphasize is that we are dealing with a very complex problem. Investigations throughout the world as well as our own have proven this beyond question. The conditions of optimum environment for plant growth include plant food, moisture, air, sunlight and temperature. Everyone must realize the difficulties attached to the maintenance of all these conditions at optimum. It is widely recognized that with any departure of any one of these conditions from the optimum or the entrance of an inhibiting toxic factor the plant may be affected in its growth and is often rendered more susceptible to diseases which would scarcely invade the tissues when in normal vigor.

The root rot problem is therefore more than a "one man job," and as long as we continue to treat it as a single line of research our progress is bound to be slow. That is to say, it is not a problem in chemical research, or pathological research alone. In the past it has been treated more or less like a game of volley-ball. First it was taken up by the pathologists, then thrown at the chemists, back again at the pathologists and, finally, once more at the chemists. It is a research problem involving the imperative close cooperation in lines of chemical or soil research, the morphological study of the plant tissues and plant processes as well as the pathological investigation of the parasitic and saprophytic characteristics of the associated fungi and possibly other yet unforeseen factors.

Our investigations to date are extremely encouraging, to say the least, and I feel that its solution is highly probable if the proper cooperation can be obtained.

A Study of the Cane Borer, *R. Obscura*, and Its Parasite, *C. Sphenophori*, at Paauhau Sugar Plantation Company

By C. E. Pemberton

Introduction

With the gradual reduction in acreage of Yellow Caledonia cane, since 1918, in the Hamakua district of the island of Hawaii, and its replacement with the varieties D 1135 and H 109, there has been a noticeable increase in damage by the beetle borer, *Rhabdocnemis obscura*, if we are to judge from the frequently expressed complaints since 1920. This increase is readily explainable from the cane variety point of view, for D 1135 and H 109 are more favorable for borer development than Yellow Caledonia. They are primarily more susceptible because softer. However, were we to attribute the increased borer damage solely to a change of varieties, we would expect similar damage elsewhere where D 1135 or H 109 have extensively replaced Yellow Caledonia. This is not so. The explanation is complex, involving a consideration of both the climatic conditions of Hamakua and the change of cane varieties in their combined influence upon the activities of the borer, as well as the meteorologic effects upon the cane, which result disadvantageously to the parasite.

At the urgent request in 1923 of Mr. F. M. Anderson, Manager of Paauhau Sugar Plantation Company, and through the suggestion of C. Brewer & Company, Ltd., a study of the situation at Paauhau was begun in February, 1924, and continued through the harvest season until October.

As the borer parasite (*Ceromasia sphenophori*) now effectively controls the pest over most of the other plantations in Hawaii, this investigation dealt almost exclusively with a study of the parasite, as it operates in Hamakua. Some fear had been expressed that its activities might be hampered by factors peculiar to the district. It was felt that perhaps an understanding of these factors, if present, might lead to their control, with a consequent alleviation of the losses. This work, therefore, has been largely a study of the parasite, in every phase of its complete cycle, and, as the data which follow show, establishes what we feel to be ample proof, that the difficulty in Hamakua is climatic and one of varietal change, rather than one of loss of vigor in the parasite or of the presence of enemies inimical to it.

As just indicated, we feel that Yellow Caledonia is less susceptible to borer injury than the varieties D 1135 or H 109, because harder. The data covering extent of borer damage among the three varieties have not been extensive enough clearly to demonstrate this, however. In fact, in some scattered counts the reverse conclusion might be drawn.

Extent of Borer Damage

The data at hand respecting the percentage of sticks damaged by borer at Paauhau and Honokaa are convincing of the importance of the losses, but not extensive. This side of the study was necessarily sacrificed in order that a thorough investigation could be made of the parasite. Estimates by Mr. Raymond Elliott, Chemist of Paauhau Sugar Plantation Company, of the extent of borer damage in several fields at Paauhau in 1923, gave an average of 26.48 per cent of the stalks damaged and in 1924 an average of 27.17 per cent. In a comprehensive series of analyses, made by him in 1924, on sound and borer-injured cane from five separate fields, his conclusions show a surprising sugar loss occurring in these fields. These data, presented at the Third Annual Meeting of the Association of Hawaiian Sugar Technologists in October, 1924, indicated an average monetary loss for the five fields of $42.30 per acre, with sugar at 7 cents. In this computation, 27.17 per cent of the sticks analyzed were borer injured. If we apply these figures to the data shown in Table 1, covering counts made by the writer at Honokaa, Paauhau and Hakalau during 1923, we may logically assume that the cane borer actually levies a heavy tax on large areas of cane in Hamakua and to some extent, occasionally, in certain low fields as far along the coast as Hakalau. When we see, however, the extent of control that is being constantly exerted over the borer by the introduced parasite, as shown in Table 2, no stretch of the imagination is needed to comprehend what a really large loss would inevitably occur, were it not for this continual parasitic check. With losses in Hamakua as they now are, in spite of a 44 per cent destruction of the borers by the parasite, what would they be without this check?

Table 1 should give a fair estimate of the extent of borer damage as it occurred in 21 fields of Honokaa Sugar Company in 1923. A total of 15,900 sticks were examined. This examination showed an average of 22.7 per cent of the sticks injured to some extent by the borer. These counts were made at random over the fields, and though not large, indicate distinctly that the borer problem is one of importance on the plantation. The fields show damage ranging from nothing to 48 per cent, the cane being mostly D 1135. Of interest is a count of 1,000 sticks of Uba cane, under harvest in Field 24, Honokaa Sugar Company, where no borered sticks were found whatever. This is not always the case, as later observation showed, but Uba is clearly less susceptible to borer injury than D 1135 or H 109.

In general, the cane at Honokaa cut in 1924 appeared to have somewhat less damage than in 1923, owing to the greater amount of short ratoons cut and in part to rat control. A brief discussion of the relation of short ratooning to borer development occurs elsewhere in this paper.

Borer damage in Hamakua is usually much more severe in fields below the 1000 ft. level than above. The lower the fields, generally the more acute the damage. The only high fields in Table 1 are the first five. The average damage for these is well below that of the remaining sixteen fields, taken collectively.

Apart from the percentage counts of borer damage, made by Mr. Elliott, referred to above, three counts were made at Paauhau in April, 1923, as shown in Table 1. These covered a total of 4,500 canes in three fields. An effort was

made to secure counts giving average conditions. They show an average of 12.5 per cent of the sticks damaged, with a maximum of 18.6 per cent in a field of H 109 and a minimum of 4.8 per cent in a field of D 1135, the Yellow Caledonia field falling between with a damage of 14.3 per cent. These figures can only be indicative of the occurrence of considerable loss, as they are not extensive enough to accurately measure the field loss or varietal susceptibility.

As further shown in Table 1, losses from cane borer may be considerable even at Hakalau. At the request of Mr. Ross in August, 1923, a count was made in Field 2, Hakalau Plantation Company, in 15 months old, short ratoon, Yellow Caledonia cane. This field, at a low elevation, showed a good deal of damage, though, as is frequent in this variety, many of the canes damaged would bear the injury only in a single joint. The count, covering 6,000 sticks, gave a borer damage of 16.8 per cent. This should be close to the actual percentage of canes borer injured in this field. It is believed that this degree of injury is exceptional for Hakalau, however.

Borer Parasitism at Paauhau

The complete results embodying the study of parasitism of the cane borer at Paauhau Sugar Plantation Company are summarized in Table 2. A brief discussion with conclusions drawn is necessary in explanation of the facts indicated therein and in Tables 3 and 5 elaborated from it.

A fairly exact understanding of the operations and benefits derived from this parasite, can be obtained through careful dissection of the borer channels in the canes, providing these dissections are made on a large scale, covering representative areas over the fields under investigation. These channels, old and new, contain the entire history of what has already occurred or may be occurring in the unceasing struggle between the borer and its enemy, the fly. Old channels, often formed 15 to 20 months previous to the examination, unless completely destroyed or cleaned out by ants, contain the record of parasitism or non-parasitism. If a borer-grub has succeeded in developing to maturity without being found and destroyed by the parasite, the original borer cocoon, from which the beetle has hatched out, still lies in the channel, empty. Being empty is indicative that the beetle matured and escaped unharmed. If the record is more recent and a grub has matured, escaped attack by the parasite and changed to the pupal stage, which is then uninteresting to the fly maggot, this borer pupa lies exposed for our record also, as an unparasitized individual. However, if a grub, many months, or even a year or more previous to our examination, has been reached by the wriggling maggots of the fly, and thus destroyed by them, the cocoon which the grub weaves, even though parasitized, will contain the empty shells of the fly pupae which have developed from these maggots. These empty shells (puparia) are absolute evidence of parasitism, even though the borer-grub had been destroyed and the flies developed and escaped long since. Again, these borer-cocoons may contain the fly pupae or developing flies themselves, which indicates recent parasitism. Still further, the borer channel may contain a living borer grub. The dissection of this shows readily the presence or absence of parasites, in the form of pale, white maggots of varying size, dependent upon their period

of residence within the body of the grub. The dissection then of each borer channel reveals the history, past and present, of the work of the parasite, indicating wherein it has succeeded in reaching grubs and just how often it has failed.

During the 8 months time devoted somewhat intermittently to these dissections, a total of 11,704 borer channels, in 5,819 grub-injured canes, were dissected out in their varied ramifications, covering four fields carefully and two in part.

The data for each variety of cane, in each field, were segregated. As no clearly marked difference could be discerned in degree of parasitism in one variety of cane over another, this differentiation in variety is not shown in Table 2.

The actual percentage of borer grubs destroyed by the parasite during the entire period of growth of the cane in the 6 fields examined, ranged from 36.5 per cent to 56 per cent, with an average for the 6 fields of 44.6 per cent. This is a much more satisfactory degree of parasitism than we had anticipated. During the examinations, parts of fields at times showed very low control. Often for a week or more, the canes consistently showed parasitism ranging below 10 per cent. However, there was considerable fluctuation in each field. This demonstrated the need for a wide series of records, and the average for each field, as a whole, as finally summarized, was much higher. These localized spots, both at Honokaa and Paauhau, where the parasitism is often very low, are generally areas of dense growth in the bottom of hollows, large and small, or in low fields where the cane has been long-ratooned, has been much bent over and often broken by wind and where trash and sometimes weed and grass growth has become thick, matted and protective of the hidden canes near the ground, thus almost completely excluding the fly in its efforts to reach the grub infested parts of the canes.

A total of 2,910 borer grubs were cut open and evidence of parasitism therein determined. Of these, 12.3 per cent contained larvae of the Tachinid fly, totaling 1,107 maggots, or an average of 3.0 per parasitized grub. The greatest number of maggots found in one grub was 12. Many grubs were opened that contained but 1 maggot, some with 9 or 10 and three with 11 maggots. As many of the grubs examined might have become parasitized in the field, before maturing, if left undisturbed, we cannot use this data as the absolute test of the degree of parasitism occurring in the fields examined. It only gives data on the seasonal activity of the parasite. The actual extent of parasitism is determined from a borer cocoon examination. As described above, the past as well as the present history of cane borer parasitism in each stick, is bound up in the cocoons in the stalk.

From a total of 6,171 cocoons opened and examined, 2,638 contained fly pupae or empty fly pupal shells (puparia). This gives an actual parasitism, based on the whole series of cocoon examinations combined, of 42.7 per cent, and as given above, if based on the separate totals of the 6 fields, a parasitism of 44.6 per cent. These figures should fall close to the actual degree of control exerted by the parasite over the borer in the Paauhau fields studied.

A total of 7,331 fly pupae or puparia were removed from these 2,638 cocoons, which gives an average of 2.8 per cocoon. This is close to the figure recorded

above (3.0) for the average number of fly maggots occurring in living borer grubs. The greatest number of fly pupae or puparia per cocoon was 11. Many contained only one and several had 8, 9 and 10 per cocoon.

These are interesting data, bearing on the life habits of the parasite, for they check well with similar data computed by Mr. Muir in his original observations on this parasite at the time of his discovery and introduction of it to Hawaii.

As already stated, many old borer channels in the cane become entirely cleaned and occupied by ants, particularly the big headed brown ant *Pheidole megacephala.* As nothing of the parasitism record remains in these channels, they must necessarily be left out in the computations. There are many of them. During the period of borer study at Paauhau, a total of 2,069 such channels were cut out, from which no evidence remained with which to record parasitism data.

The information in Table 3 is illuminating in explanation of the seasonal activity of the parasite. It shows distinctly that the parasite is much more active and effective during the summer months in Hamakua than in the winter. In February, March and April, the percentage of developing parasitic larvae or pupae present, as compared with the percentage of old, empty, fly pupal shells (puparia), was less than half that of May, June, July or August. In other words, in the summer months, fly larvae, pupae and hence adult flies, were easily twice as numerous, by percentage counts, as in the spring, fall or winter months.

In the entire series of examinations the records of parasitism and borer attack, as they occurred separately in the top, middle, lower part and bottom of each stalk, were segregated for each section of the stick. A comparison of these data gives us useful information. This tabulation is shown in Tables 4 and 5. Of 11,704 borer channels examined, 16.6 per cent occurred in the top portion of the stick, 22.4 per cent in the middle section, 31.5 per cent in the lower 3 feet and 29.5 per cent in the bottom one foot of the stick. Thus the first four feet of cane above ground contained 60.9 per cent of the borer channels and the bottom one foot of cane almost one-third of the total number in the entire stick.

As shown in Table 4, the parasitic control of the grubs is poorest in the bottom of the stick and best in the second, third and fourth feet of cane. It is also fair in the middle and top. These are not necessarily iron bound conclusions. They are based only on the facts as they appeared in this particular investigation. It is safe to conclude, however, that in general, under the present methods of agriculture in Hamakua, the bottom portion of the canes will have the most borers and show a lower degree of parasitism than in any other part of the stick.

A careful watch was kept for predatory or parasitic enemies of the fly, in all stages, during the entire period of study. None were found. No indications of parasites on the fly larvae were detected and nothing but flies emerged from a large number of fly pupae saved.

The fields selected for study represented long and short ratoons. No decided difference could be seen in the degree of borer-parasitism between the two, though field examinations both at Honokaa and Paauhau in young cane up to 1 year of age, in general show a higher degree of parasitism than in older cane. The amount of borer damage in any field must necessarily be increasingly greater the older the cane becomes. The accumulated damage per stick is naturally greater in cane exposed to borer for 2 years than 1½ years or any shorter period. This

is self evident and in spite of occasional casual comparative counts in long and short ratoons, which may show more damage in the latter; any one field will, of course, have more damage the longer it remains in the field. It is simply accumulative.

The great improvement in juice purity and sugar yield in Hamakua, in recent short-ratooning tests, particularly at Honokaa, clearly demonstrates that the same operation, if adopted as a means of borer control, in no way endangers the sugar output of a field.

Table 6 gives data secured by Mr. Swezey at various plantations on Maui, Oahu and Kauai during 1924-25. These figures show in general a fair degree of parasitism at each place. They were obtained incident to other work and hence do not cover large counts, excepting at the H. S. P. A. Experiment Station in Honolulu. This count shows a fairly satisfactory degree of control. They all tend to show that the Tachinid fly is no different in its operations at these places than in Hamakua, and further bears out our contention that the difficulty in Hamakua is climatic and one following cane varietal change, as explained elsewhere herein.

Factors Favoring the Borer in Hamakua

The following tables and conclusions drawn from them would indicate that the Tachinid fly in Hamakua possesses, in no lessened degree, the same vigorous potentialities for control of its host, the borer, that it has elsewhere in Hawaii where little borer damage occurs. In view of this we must look for other explanations of its inability to control this pest as thoroughly in Hamakua as in most other cane regions in Hawaii.

The frequent heavy winds of Hamakua, in their effect upon the cane, in combination with the change of variety from Yellow Caledonia to softer canes, would seem to explain the difficulty, but not remedy it. Very early in the growth of the cane, particularly in ratoons, borer infestation can be found. Fairly heavy infestation is often seen in cane only 4 or 5 feet high, if careful examination is made in the lowest joints. This results from the accumulation of adult beetles in the vicinity, in mature cane, the left overs from the crop that has just been removed and especially the heavy grub infestation in the stools themselves, left underground or near the surface in the stubble after harvesting. Much of this has been observed in borer-infested fields just harvested. As the cane continues growing, the borer grubs developing lie well exposed to parasitic attack usually until the cane is at least a year old. By then, in the low irrigated fields and hollows, it begins to bend over, frequently blows down in spots, and has commenced accumulating fair amounts of trash about the ground. Up to this point, as stated, conditions are satisfactory for parasitic attack on the grub, which permits a gradual multiplication and accumulation of the adult flies. From here on, however, this fly-increase, this perceptible gaining of the parasite over the borer, falls off. The balance then somewhat favors the borer. Were it not for the wind, in its periodic cracking and splitting effect upon these trash concealed parts of the stalks, the beetles would necessarily be obliged to place their eggs well above the trash, for they normally oviposit beneath live leaf sheaths where the newly found rind of the stick is not so hard as on the old joints.

The cane beetle has a very strong affinity for souring cane, for splits in the stalk, for spots opened by rat attack. This instinct is strong and has been repeatedly observed, for many years, by all who have studied the insect. Hence these cracks and breaks near the bottom of the canes, in and under the trash, which becomes heavier and more compacted as the cane grows older, furnish ideal spots for the beetle to place its eggs. It readily penetrates any trash, while the fly cannot. Were it not for such wounds in the lower part of the canes, no suitable tissue would exist there for beetle oviposition. In such cracks, breaks and splits, the eggs hatch and the grubs feed and develop to maturity in great part safely excluded from parasitic attack, because immersed in much compacted trash. We have good evidence of this in Tables 5 and 2, which distinctly show that the greatest number of borer channels at Paauhau, occur in the lower part of the stick and that the lowest degree of parsitism occurs there also.

On other plantations in Hawaii where there is no perceptible wind damage, the borer is well controlled by the parasite. Trash accumulates at many of these places, such as at Ewa, in even greater quantities than in Hamakua, because the yields are much heavier, yet there is no accumulation of suitable egg-laying spots in the trash-covered bases of the canes and the beetle must necessarily lay under the leaf sheaths well up on the cane. Most grubs then develop in places exposed and readily reached by the parasite. Suckers appearing in such trash can be suitable for borer development, but the period of their growth through this cover is short, and hence exposed to beetle attack while under the trash for a much smaller period than in broken or split cane-bases lying immovable within the trash.

In connection with this whole subject, we would venture the opinion that Yellow Caledonia is more wind-resistant than D 1135.

The relation of wind to borer damage was investigated briefly in Kohala. One field of D 1135, then under harvest, was examined. Borer damage in the small area examined was heavy. In tip canes at the same elevation damage was slight. There is no disputing the contention that this cane is more wind resistant than D 1135.

Occasionally the beetle borer accumulates to a noticeable degree in spots even on Oahu. This is in old cane usually. The older it becomes the more dead and fermenting canes naturally can be found in the trash. This softened material beneath and in the trash, furnishes suitable environment for beetle oviposition and grub development in tissue safely fortified against entrance of the fly.

General Conclusions

From the above, our only conclusion can be that plantations exposed to frequent and heavy winds in Hawaii, must inevitably suffer more or less from cane borer, when it becomes necessary to plant canes non-wind-resistant or comparatively soft. Some of the seedlings propagated at the Experiment Station, which were exceptionally soft, have proven highly susceptible to borers wherever planted.

We see no artificial method of cane husbandry which could be practically applied to completely remedy the trouble. We cannot recommend a change of varieties in Hamakua, for D 1135 is proving its high worth as a splendidly adapted cane for that district.

The future development of new varieties and tests of imported canes, such as the newly introduced Java seedlings, may in time offer a solution. The study and use of wind-resistant canes in Formosa is interesting, and may ultimately show us the value of such procedures in application to our wind-swept localities.

Several careful strippings and the clearing away of trash about the base of the stool should result in satisfactory parasitic control of the borer in Hamakua, but this expensive operation is probably impractical for more than one reason. Such clearing of the stool, for instance, would involve the piling of trash in the space between the rows and interfere with proper irrigation. Also, vigorous cane much over a year old is almost impossible to clean properly, at the base, because of the intricate bending and interlacing of adjacent stools in adjoining rows. Wider planting of the rows would serve to assist the parasite in its entrance of the stool and serve to spread out the trash and lessen the thickness of the blanket. It is doubtful, however, if a 6- or 7-foot spacing would prove profitable from an agricultural point of view. Were it not for this objection it should prove a useful adjunct in borer control.

The practice of short ratooning will improve the situation. Parasitism is best in young cane, for the reasons given elsewhere in this paper. Borer damage and beetle accumulation increase as the cane grows older. These two facts are indisputable. We feel that the wider the practice of short ratooning becomes, in the low fields of Hamakua, the better will be the borer control. Heavy damage as now sometimes occurs in short ratoons should not discourage one in the final acceptance of this view. The wider the policy of short ratooning, the more accumulative becomes the parasite in its operation over the entire district and the less accumulative the beetle. This is inevitable, as just inferred. It is a matter of simple reasoning, based on our knowledge of the development and interrelated habits of beetle and parasite.

We await with interest and much hope the outcome of efforts to be made during 1925 to locate further natural enemies of this pest in its native haunts in parts of the Malay Archipelago.

TABLE 1

EXTENT OF CANE BORER DAMAGE IN 1923

Honokaa Sugar Company

Field	Variety	Dates of Examination	Total No. Canes Examined	Average per Cent of Canes Borer Injured
1	D 1135	March 12	200	9.5
5	D 1135	May 26	200	2.5
7	D 1135	March	400	7.2
10	D 1135	June	600	22.3
12	D 1135	March	300	7.1
18	D 1135	February and March	900	25.6
19	D 1135	July	200	12.0
22	D 1135	June and July	1000	16.7
24	Uba	May	1000	0.0
25	D 1135	June	600	45.5
26	D 1135	March and August	800	16.1
28	D 1135	May, June, July and Sept.	1700	27.1
29	D 1135	August and September	800	34.6
30	D 1135	February, March and Aug.	1000	45.6
33	D 1135	August and September	1800	14.6
34	H 109	February and August	1500	48.0
35	H 109	July	800	18.6
36	D 1135	March	900	22.0
37	D 1135	February	500	47.2
38	D 1135	September	600	35.1
D	D 1135	May	100	20.0
	Total and Averages		15,900	22.7

Paauhau Sugar Plantation Company

1	H 109	April	1000	18.6
17	D 1135	April	2500	4.8
6-a	Yellow Caledonia	April	1000	14.3
	Total and Averages		4500	12.5

Hakalau Plantation Company

2	Yellow Caledonia	August	6000	16.8

TABLE 2

Parasitism of the Cane Borer (*R. obscura*) by the Tachinid Fly (*C. sphenophori*) at Paauhau Sugar Plantation Company, 1924

Field	Date of Examination	Number Canes Examined	No. Parasitized Borer Larvae Present	No. Groups Fly Pupae Present	No. Groups Empty Fly Puparia Present	No. Unparasitized Borer Larvae Present	No. Borer Pupae Present	No. Borer Beetles Emerged	Parasitism based on All Forms, Including Larvae	True Parasitism Columns 5, 6, 8, 9	Remarks
1	Sept.	511	73	82	386	295	116	330	42.2	51.2	Mixed D 1135-Yellow Cal. and H 109, rat. 18 to 19 months old at time of examination.
	Oct.	514	55	52	296	645	98	386	26.3	41.8	
Field 1 Totals		1025	128	134	682	940	214	716	33.5	46.7	
2	June	1759	125	111	440	552	191	635	32.4	40.8	Mixed D 1135-Yellow Cal. and H 109, rat. 18 to 19 months old at time of examination.
	Aug.	105	12	15	26	149	64	65	16.0	24.1	
	Sept.	155	8	18	44	119	74	104	19.0	25.8	
Field 2 Totals		2019	145	144	510	820	329	804	29.0	36.5	
2A	Mar.	162	3	5	57	59	23	59	31.0	43.0	H 109, rat. 16 months old at time of examination.
7	Feb.	200	6	3	62	55	27	61	33.4	42.4	Yellow Caledonia. Long ratoons.
	Mar.	472	11	22	181	96	53	85	47.6	59.5	
	April	507	11	17	237	246	130	233	30.1	41.1	
	May	312	14	21	127	97	58	118	37.2	45.6	
Field 7 Totals		1491	42	63	607	494	268	497	36.0	46.6	
14	April	400	4	21	117	104	58	94	35.6	47.5	Yellow Caledonia and H 109. Long ratoons.
	May	470	37	64	164	102	137	279	33.8	35.4	
Field 14 Totals		870	41	85	281	206	195	373	34.4	39.1	
15½	Feb.	90	0	2	32	12	21	13	42.5	50.0	D 1135. Long ratoons.
	Mar.	90	1	0	36	19	5	16	47.3	63.1	
Field 15½ Totals		180	1	2	68	31	26	29	45.2	56.0	

Note: In the June examinations of Field 2, 164 canes were examined by Mr. Elliott at Paauhau Sugar Plantation Company.

Most of the cane of Table 2 lying below 900 feet elevation.

TABLE 3

Seasonal Activity of Borer Parasite *C. sphenophori*

Month, 1924	No. Parasite Larvae and Pupae Found	No. Empty Parasite Puparia Found	Percentage of Developing to Emerged Parasites Found
February	11	94	10.4
March	42	294	13.2
April	53	354	13.0
May	136	291	31.8
June	236	440	34.9
August	27	26	50.9
September	181	430	29.6
October	107	296	26.5

TABLE 4

Parasitism of Cane Borer in Top, Middle, First 3 Feet and Bottom of Cane Stalk. Borer Larvae Included in Calculation.

Top of Stalk			Middle of Stalk			First 3 Feet of Stalk			Bottom of Stalk		
Parasitized	Not Parasitized	Per Cent Parasitism	Parasitized	Not Parasitized	Per Cent Parasitism	Parasitized	Not Parasitized	Per Cent Parasitism	Parasitized	Not Parasitized	Per Cent Parasitism
546	1239	30.5	811	1304	38.3	1005	1843	35.2	636	1697	27.2
Actual Parasitism by Section Borer Larvae Excluded in Calculation											
481	705	40.5	633	752	45.7	913	995	47.8	611	1081	36.1

TABLE 5

Part of Stalk Attacked by Borer—All Fields Combined

Number of Borer Channels in 5,819 Injured Stalks

Top	Middle	First 3 Feet Above Bottom	Bottom 1 Foot
1945	2622	3688	3449

TABLE 6 *

Cane Borer Parasitism on Maui, Oahu and Kauai

Locality	Dates of Examination 1924	No. Groups of Fly Pupae or Puparia	No. Beetles Emerged Plus Beetle Pupae	Percentage of Parasitism
Experiment Station, H. S. P. A.	March 7-15	326	198	62.2
Experiment Station, H. S. P. A.	April 9-10	375	165	69.4
Experiment Station, H. S. P. A.	May 2-3	238	368	39.2
Experiment Station, H. S. P. A.	October 14	44	13	77.1
Experiment Station, H. S. P. A.	December 19	80	75	51.6
Pioneer Mill Company, Ltd.	March 18	6	35	14.6
Pioneer Mill Company, Ltd.	March 18	38	13	74.5
Pioneer Mill Company, Ltd.	March 18	3	5	37.5
Wailuku Sugar Company	March 20	17	52	24.6
Wailuku Sugar Company	March 20	41	93	30.5
Kaeleku Sugar Company, Ltd.	March 21	30	7	81.0
Maui Agricultural Co., Ltd.	March 25	17	28	37.7
Olowalu Company	March 26	12	23	34.2
Hawaiian Commercial & Sugar Co.	March 26	2	13	13.3
Hawaiian Commercial & Sugar Co.	March 26	7	10	41.1
Waipio, Oahu	April 29	41	19	68.3
Koloa Sugar Company	July 12	68	22	75.5
Kahuku Plantation Company	Jan. 2, 1925	27	31	46.5
Kahuku Plantation Company	Jan. 2, 1925	10	8	55.5
Kahuku Plantation Company	Jan. 2, 1925	25	45	35.7
		1407	1223	46.5

Progress of the Raw Sugar Industry†

By W. van H. Duker

Soon after your Chairman had requested me to report to you on the "Progress of the Raw Sugar Industry," I realized that, in order to do so, we must first agree upon what we understand by progress; in other words, we must have a standard with which to measure progress. This, in itself, is not quite so simple, but, in answer to a request made to several prominent men engaged in the sugar industry for a definition of what constitutes progress in the sugar industry, I think Mr. Herbert Walker gave one most to the point when he considers progress "the ratio between service rendered and energy expended," to which he modestly added that he preferred to leave the development of the ratio to others. Again, we may consider that the industry makes progress the nearer it fulfills its object as a commercial enterprise.

* Data secured by Mr. O. H. Swezey.

† Presented at Third Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 27, 1924.

At the annual convention of the United States Chamber of Commerce, the following definition was agreed upon as the object of business: "The function of business is to provide for the material needs of mankind, to increase the wealth of the world and the value and happiness of human life."

However, to keep our feet on the ground and to write a report acceptable to this convention, I decided to confine myself more particularly to the technical development of the raw sugar industry of Hawaii, to facts and figures relating thereto, the causes of its development and the possibilities of its continuance. Thirty-three years ago the world's sugar production was 6,000,000 tons:

Cuba's production was	675,000	tons
Java's production was	360,000	"
Philippines' production was	160,000	"
Hawaii's production was	130,000	"

For the crop 1923-1924 (the nearest estimate at this time) the world's sugar production is 20,000,000 tons.

Cuba's sugar production is	4.200,000	tons
Java's sugar production is	1,830,000	"
Philippines' sugar production is	525,000	"
Hawaii's sugar production is	678,000	"

In addition to this, I submit the following statistics, while I would venture to remind those who doubt if we make progress at all, that a developing industry has much in common with that of a human life; a child's weight and height double themselves every six months, year, two or three years in the first years of its life, while an adult stops growing or grows so slowly as to be hardly aware that he is doing so. Would you deduce from this that a boy of six years of age is superior to a man of forty?

Production of sugar by islands in periods of 10 years each:

	Hawaii	Maui	Oahu	Kauai
1894-1904	1,120,524 tons	478,188 tons	563,083 tons	576,623 tons
1904-1914	1,643,021 "	1,195,807 "	1,259,294 "	874,077 "
1914-1924	2,059,257 "	1,362,645 "	1,417,560 "	1,093,251 "

Totals for the Group

1894-1904	2,738,418	tons
1904-1914	4,945,199	"
1914-1924	5,932,715	"

In analyzing what has caused this rapid development, we find that cooperation of capital and science are the very foundation. As early as 1883 the sugar planters combined in their effort to secure suitable labor supply, which combination later developed into the Hawaiian Sugar Planters' Association with its many and ever increasing number of fields of activity.

In 1895, the Experiment Station was organized and from that time on dates the more tangible development of the technical side of the industry. Studying the past records, we find a worthy list of inventions to the credit of progressively spirited local sugar men who have in no small measure been instrumental in making the industry what it is today.

Of the many locally developed labor saving devices and improvements of manufacturing machinery which have lasted through the years and have proven their worth, we have:

1. Weston Centrifugal, 1855, by D. M. Weston, Manager, Honolulu Iron Works Company.
2. Juice Strainer, Cush Cush Elevator and Automatic Bagasse Feeder, 1895, by John A. Scott, Manager, Hilo Sugar Company.
3. Wick's Cane Unloader, 1901, A. Wick, Chief Engineer, Honokaa Sugar Company.
4. Rotary Bagasse-Feeder, 1904, Max Lorenz, Consulting Engineer, H. Hackfeld & Company.
5. Clarifying Centrifugal, 1909, E. W. Kopke, Consulting Engineer, Honolulu Iron Works Company.
6. Messchaert Juice Grooves, 1913, P. A. Messchaert, Superintendent, Oahu Sugar Company, Ltd.
7. Searby Shredder, 1914, Wm. Searby, Superintendent, Hawaiian Commercial & Sugar Company.
8. Ewart Bagasse Conveyor, 1916, A. F. Ewart, Works Manager, Honolulu Iron Works Company.
9. Ramsay Maceration Scraper, 1916, W. A. Ramsay, Manager, Catton, Neill & Company.
10. H. I. W. Company, Patented Steel Check, 1916, W. G. Dyer and A. F. Ewart, Engineers, Honolulu Iron Works Company.
11. Foster Motor Fuel, 1917, J. P. Foster, Superintendent, Maui Agricultural Company, Ltd.
12. Meinicke Chutes, 1921, J. Meinicke, Chief Engineer, Maui Agricultural Company, Ltd.
13. Peck's Revolving Juice Screen, 1922, S. S. Peck, Consulting Chemist, Alexander & Baldwin, Ltd.
14. Cast Steel Top-Cap with Hydraulic Jack Incorporated, 1911, W. G. Hall, Manager, Honolulu Iron Works Company.

The Chemical Division of this Association is, of course, primarily interested in the question of recovering the largest quantity of sugar out of the cane at the lowest possible cost.

Taking as a basis the average per cent sucrose recovery for the period of the years 1909 to and including 1913, we find this at 85.46 per cent (85.4698). The average total recovery of sucrose during the period of the next ten years is 87.558 per cent.

During the period (1914 to 1923) 6,545,297 tons sucrose were delivered in the cane to the factories. If the percentage sucrose recovery had remained at the average figure for the five years 1909-1913, 5,791,151 tons sugar (at 96.6 Pol.)

would have been the output. Due to the application of technical knowledge and the improvement of equipment, 5,932,715 tons sugar at 96.6 Pol. were marketed or 141,564 tons *more*. At as moderate a valuation as $75.00 per ton this has meant an additional $10,617,300 for the ten years.

Two factors have been at work to make such an accomplishment possible; first of all, the period of increased efficiency and standardization, which period I should like to call the Gartley period, since he was the man who succeeded in arousing the necessary interest and enthusiasm; and, secondly, the exchange of mill data and the annual synopsis thereof. To those who depend in their judgment upon information contained in these data, this synopsis or study of factory accomplishment is of the greatest value.

I hope that at this meeting some details of this synopsis as well as some desirable alterations and additions to the weekly report of Comparative Mill Data will come up for discussion. These reports are extensively used and its publication eagerly awaited by the ambitious engineers and factory superintendents. If, in addition to the data now already published, a figure could be included giving, weekly or monthly, the percentage total sucrose recovery to date for each factory, in order to draw more attention to this figure and less to the extraction data, which, after all, is only an intermediate figure often wrongly taken for total output or yield, its value would be materially increased.

As an illustration of what has been accomplished in a group of factories, not so much by any radical change of equipment but by a systematic and sustained effort of the plantation management in cooperation with those immediately in charge of operation, I quote the following:

Factory Losses Expressed in Per Cent Sucrose Recovered on Sucrose in Cane

	Waiakea Mill Co.	Laupahoehoe Sugar Co.	Kaiwiki Sugar Co., Ltd.	Hamakua Mill Co.	Honokaa Sugar Co.
1920	82.8	88.3	85.9	79.0	84.5
1921	83.6	86.3	85.7	78.6	81.6
1922	85.3	87.4	86.0	80.3	85.3
1923	86.6	87.7	86.5	86.2	86.6
1924	86.8	88.2	87.2	86.7	87.4

	Niulii Mill & Plantation	Halawa Plantation, Ltd.	Union Mill Co.
1920	74.0	76.5	77.3
1921	80.0	71.7	74.4
1922	81.8	78.0	80.0
1923	81.8	78.8	82.6
1924	82.6	83.7	83.2

However, great and remarkable as the technical development of our industry has been in the past twenty years, I believe that from now on our greatest gain must come from a further improvement in the quality of the cane as we receive it at the mills, since our records show clearly that no factory improvement is able to recover the losses due to deterioration of the raw material itself and I heartily agree with the statement of Mr. J. P. Foster, of Paia, that the future

development depends on our success in learning more about the quality of the impurities and in overcoming its influence on the yield.

In a broad sense, the development of the sugar industry is practically unlimited. The consumption of sugar in the United States in 1922 was 112 lbs. per capita. In 1900, it was 70 lbs. In Europe, the per capita consumption is less but up to the outbreak of the war it was increasing rapidly and the increase is certain to be resumed as pre-war conditions are reestablished. The world's supply of sugar for the year 1924 is estimated at 20 million tons. The consumption will about equal this supply, but if the per capita consumption of the world's total population were equal to that of the United States 80 million tons would be required to supply the demand.

According to evolutionists, it took millions of years to form a tadpole and other millions of years before the tadpole dropped its tail and crawled out to live on land. Growth is slow. This is one scientific principle that has never been disputed, though it is little recognized in the modern world.

Great problems are immediately ahead of us, well worth the study and thought of everyone connected with the technical development of the industry. Eliminating the refinery operations and making refined sugar direct from the cane is one of them; recovering the sucrose now lost in our final molasses and amounting to from 6 to 8 per cent of the total supplied to us by nature is another.

Sugar Cane Breeding at Coimbatore, India*

By T. S. Venkatraman †

Introduction

Leaving out of account for the time sporadic, often unauthenticated and generally unsuccessful attempts at growing sugar cane from seed, the first success in this direction in India was achieved in the year 1911 by Dr. C. A. Barber, C. I. E.[1]

This led to the foundation at Coimbatore of a sugar cane-breeding station for the whole of India with the definite object of improving the quality of the indigenous Indian canes. The very poor quality of these canes—some of them the poorest specimens of cane in the world—is one of the main reasons for the very low acre yields obtaining in India. The low yields render it necessary for India to import from outside, annually, refined sugar valued in most years at over fifteen crores of rupees or ten million sterling in spite of her possessing within her own confines nearly half the world area under sugar canes.

* Presented in part at Third Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 27, 1924.

† Government Sugar Cane Expert, Coimbatore, India.

In view of the increasing attention that, in recent years, is rightly being given to the breeding of sugar canes in various parts of the world, it is thought it might be of some use to briefly sketch in this note certain details of the technique as adopted at the Coimbatore station. This increased attention is not a little due to the outbreak in certain localities of new, little understood and serious diseases of the cane crop. Certain noticed differences between the Indian work and that done elsewhere, together with the apprehension that the Indian work is but little known outside as judged from references in published papers, have been additional inducements for writing this note.

Need for Careful Study of Parents

While the wide diversity of forms from a variety even when self-pollinated, is easily the first observation that strikes a sugar cane breeder as he starts his work, a certain similarity in the seedlings obtained from the same parent soon forces itself on his attention as the work extends. The indigenous Indian canes are of a type quite distinct from the tropical kinds and striking differences between the seedlings raised from each class soon revealed themselves. It was further found that subtle, but none the less appreciable differences, separated batches of seedlings obtained from even allied parents.

It was found that the tropical canes generally yielded types unsuitable for introduction into Northern India with its short growing season for cane and the rigours of winter, frosts not being uncommon in certain localities; and over 80 per cent of the Indian cane area is situated in such tracts. On the other hand, the seedlings from the only group of Indian canes which freely set seed proved to be no improvements on the parents; the bulk of these suggested going back in the direction of the wild *Saccharums*.

Attention was, therefore, early turned to the raising of crosses between the hardy Indian canes and the rich tropical kinds as the most promising line of work for the station. This line has proved so fruitful of practical results that, in recent years, all the lakh or lakh and a half of seedlings raised each year have been obtained after definite and often complicated cross pollinations.

Realizing that the conditions of growth for cane in Northern India are far from satisfactory, an early collection of the wild *Saccharums* was made with a view to use them as parents and their field characters carefully studied. This day some of the most useful seedling canes, already introduced into cultivation in North India contain the wild blood in one or more of their grand or great-grandparents; and, it is believed, that their success under the trying conditions is largely due to this parentage. Though more than one wild *Saccharum* was used in the cross pollinations, *Saccharum spontaneum* alone has been found of value.

For designing cross-pollination operations one of the first essentials is a knowledge of the type of seedlings each parent gives rise to. Consequently, every variety that happened to arrow had its flowers collected—if possible after selfing—seeds sown and the characteristics of the resultant population recorded. The data, so far collected, though far from being accurate for drawing definite conclusions as to the inheritance of characters in the sugar cane are of considerable practical use in designing the crossings. Inherent difficulties in the work have so far prevented the elucidation of any laws in the matter of inheritance.

It has been found for instance, that vigor and hardiness could be induced in a population by crossing with *Saccharum spontaneum;* that such crossing appreciably lowers the sucrose and purity in juice; that short but erect seedlings are obtained from mating with Mauritius seedling No. 1237; that increase in sugar contents could be secured by using Barbados 208, Vellai, B. 3412, P. O. J. 100 and Co. 214; that one should be prepared for considerable amount of bad habit and spotting of leaves if any of the members of the Indian group of Saretha canes are used as parents; that early maturity could be induced by using Co. 214, D. 74 and 100 P. O. J., and that late maturity generally results from using *Saccharum spontaneum.*

Selfing and Use of Cloth Bags in Sugar Cane Breeding

The Coimbatore experience in the matter of selfing is rather limited as it was early found that this line of work was not likely to be of use in the solution of the Indian problem. Enclosing sugar cane flowers inside cloth bags either for selfing or for protecting the artificially cross pollinated arrows from other undesired pollen had also soon to be given up as serious defects were noticed.

Firstly, the bagging was found to have an adverse influence on the seeding of the enclosed arrow attributable apparently to the rather unnatural conditions obtaining inside of the bags; the temperature inside of the bags was found to be higher than that outside, sometimes, by as many as ten degrees.[2]

Secondly, it was found that cloth of even fine texture did allow a certain amount of pollen to pass through its meshes. On more than one occasion arrows carefully bagged showed in the resultant seedlings unmistakable indications of foreign pollen. One rather remarkable instance of the kind was the rather free germination of an arrow enclosed in muslin, the arrow not possessing any fertile pollen of its own. In this instance the seedlings obtained showed on germination unmistakable signs of the blood of a wild cane flowering in close vicinity.

Certain observations made while extensive bagging was in practice are here recorded. The bags in the field need constant and careful supervision to prevent entry into them of rats and squirrels which often find in them a snug abode for themselves and their little ones. The rather warm fuzz comes in handy for nesting and bedding. Secondly, the bags are best held firmly in their position by planting the main supporting bamboo on the windward side and further fastening the bag to a shorter bamboo planted on the opposite side. Thirdly, the bags require constant lifting up and adjustment to prevent the vigorously growing arrow from touching the bags at the top and incidentally exposing the stigmas to pollination from outside through the meshes of the bag. Fourthly, in the event of rain the arrows soon develop fungoid growths, doubtless due to the warm and humid conditions prevailing inside the bags and need to be collected as quickly as possible after they are ready. Fifthly, the bags need inside of them some kind of frame work to stretch them out and not allow the cloth to touch the arrows inside of them. Both iron and bamboo frame works were used; the latter are preferable as they keep the bags cooler.

Cross-Pollination in the Sugar Cane[3]

As already mentioned the bulk of the seedlings at Coimbatore have been obtained through cross-pollination. The more important of the methods employed are briefly described below mentioning the advantages or disadvantages associated with each.

(1) *Emasculation*: After trial for two years emasculation had to be given up as unsuitable because of (a) the extreme delicacy of the floral parts, even a violent bending of the axis sometimes prejudicially affecting the seeding of the arrow, (b) the minuteness of the parts necessitating the operations being done under a high magnifying lens, (c) the inconvenient height at which the operations have to be carried in the field, heights of fifteen feet from the ground not being uncommon and (d) the slowness and the paucity of results, a large number of the operated flowers withering away from the handling. If anything, it was particularly unsuited to the Coimbatore station which, in the first instance, was sanctioned experimentally for a period of five years.

(2) *Bagging Together Arrows of the Two Parents*: This consisted of bringing together inside the same cloth bag arrows of the two parents and trust to the crossing taking place inside of the bags. The method was found to possess serious defects. Firstly, it was not always possible to bring the desired arrows into the same bag however close the varieties may have been designedly planted in the first instance. Secondly, it was found that the juxtaposed plants sometimes either did not arrow at all or arrowed at different dates. Thirdly, the arrows often came out at different heights rendering their being bagged together very difficult, if not impossible.

(3) *Placing Inside the Bag Each Day an Arrow of the Pollinating Parent*: The arrow which it is desired to use for pollination is cut the previous evening, the bottom of the stalk stuck into a bottle containing water and hung up inside the bag a little above the enclosed arrow. Next morning the anthers protrude, liberate the pollen and cross-pollination is secured. The liberation of the pollen is sometimes facilitated by an operator going round the next morning and gently tapping the arrow at the right time. The pollinating arrow has to be cut at a stage when it is likely to yield the maximum amount of pollen on the succeeding day, i. e., when the anther protrusion in the arrow, which is generally from top downwards, is within one-third from the top. Sometime after the pollination the arrow has to be removed from the bag to avoid its seeds getting mixed with those of the pollinated arrow. In this method each day and for each pollination one arrow of the father has to be sacrificed. The operation has to be repeated from three to four days to ensure a satisfactory pollination of the bulk of the stigmas in the mother arrow. The method has proved very satisfactory apparently because the pollen remains in its own receptacle till actually liberated when it falls directly on the stigmas. The method has been in use at Coimbatore from the year 1912.

(4) *Dusting the Mother Arrow with Collected Pollen:* This consists in surrounding the father arrow with a tissue paper bag sometime before anther protrusion, gathering the pollen immediately after anther dehiscence and dusting the pollen over the mother arrow. The pollen has to be used almost im-

mediately after collection because it quickly loses vitality; this greatly limits the number of cross-pollinations that can be effected on a particular day. The method does not lend itself to the effecting of a large number of different cross-pollinations except with a correspondingly large number of operators. It has one advantage over the method previously described in that the arrows of the pollinating parent need not be destroyed and hence are available for pollen collection from three to four days. In this method also the pollinations have to be repeated three to four days to ensure a dusting of the bulk of the stigmas.

For sometime blowing the collected pollen on to the stigmas by means of a "blowing ball" was attempted, the pollen being kept in gelatine capsules.[4] Great economy of pollen resulted therefrom but the inevitable handling associated with it has thrown it rather into disfavour in recent years.

(5) *Dusting the Mother Arrow with Pollen Preserved Largely in Its Own Anther-Sacs:* In this method such branches of the pollinating arrow as are likely to protrude their anthers during the day are scissored off fairly early in the morning and well before anther protrusion in the arrow. Ability to pick out such branches comes easily with a certain amount of experience. The branches are now wrapped loosely in tissue paper, each paper packet containing a few of the branches. The paper packets are now stored in small bamboo baskets very much like the ones used for storing and transporting fruits and vegetables, i. e., baskets with plenty of air holes in them. Care is taken to see that in a basket the packets of only one variety are stored; this is done to avoid mixtures. The baskets are now stored until needed in the cool shade of the sugar cane plants. When the mother arrow is ready for pollination the basket with the paper packets is taken to the place, one of the paper packets gently unwrapped and the arrow branches shaken over the stigmas it is intended to cross-pollinate. If during the operation a perceptible pollen cloud is not noticed the second packet is taken out of the basket and is similarly dealt with. The chief advantage of the method consists in the fact that inside the paper packets the pollen continues viable for a longer period than otherwise, sometimes by two hours. This prolonged viability has been established both by artificial germination of the grains and also from the seed setting of the arrow after the operation. It has been found that, even if the anthers do open inside the paper packets, the pollen largely remains in the sacs and is mostly liberated only as the branches are shaken over the stigmas. This is the method now largely in vogue and has been found the most satisfactory, so far, in efficiency, economy of pollen employed and economy in the number of operators that are needed for effecting the same day a large number of cross-pollinations.

Use of Bags in Cross-Pollinations

In view of the adverse effect on seed setting and the other defects connected with the use of cloth bags already mentioned, experiments were made leaving the cross-pollinated arrows unbagged and the results obtained appear to be satisfactory. It has been found that, so long as the artificial cross-pollination is done at the right time and with plenty of the desired pollen of proved vitality, the results are by no means unsatisfactory. In such cases the desired

effect appears to be attained by the pollen employed getting a start over other wind-borne pollen that may reach the stigmas later. The efficiency of the pollination can be enhanced by surrounding the pollinated arrow with a paper cylinder at the time of dusting. The arrangement, by confining the pollen to a smaller cubic space round the arrow, secures a more efficient pollination.

It has to be admitted that unbagged crosses effected in the above manner will not furnish satisfactory material for a scientific study of the laws of inheritance in the sugar cane; but against this it has to be remembered that even cloth bagging does not absolutely rule out access to outside pollen. In breeding work undertaken chiefly with the idea of rapidly achieving practical results the method has a wide sphere of usefulness.

Cross-Pollinating Varieties Rich in Own Pollen

For a long time it was the practice to artificially pollinate only such varieties as do not possess healthy pollen of their own; such varieties were chosen because of the impossibility of the collected seed including any selfed ones. The very varied needs of the station, however, rendered desirable to employ a wide circle of parents including those which possess healthy pollen of their own. Experience gained during the last half a dozen years has shown that the desired crosses with but very little chances of selfed seeds could be obtained even from the latter class of varieties by pollinating the mother arrow at the right time and with plenty of the intended pollen well before the dehiscence of its own anthers. In these cases the desired result appears to be obtained from the dusted pollen getting a good start over any self pollen that may reach the stigmas later.

The crossing done at Coimbatore has mostly been between tropical canes used as mothers and the hardy Indian canes. The anthers of the former class, generally, open much later in the day than those of the latter class; a difference of two hours has been noticed in certain cases. This fact has greatly facilitated the pollination described in the previous paragraph.

Pollen Viability Tests

In all such work it is important to test the pollen used for viability at each stage. In the earlier years a great deal of time and energy was wasted owing to the non-availability of a reliable test for viability. In the year 1920, however, a satisfactory test was discovered.[5] The pollen, it is desired to test, is sown on live stigmas of *Datura fastuosa,* when viable pollen quickly germinates. Other workers have used the stigmas of the tobacco plant for the purpose.[7] Frequent tests for viability are very important in the sugar cane because of the rapidity with which it loses viability.

Preservation of Cane Pollen by Controlling Anther Dehiscence[5]

It was often found that the two varieties, it is desired to cross with each other, arrowed in different places separated from each other by railway journeys of varying periods. Experiments undertaken for preserving pollen during transport have yielded a fairly satisfactory method. The method essentially con-

sists in preventing the anthers from protrusion and dehiscence by creating humid conditions around the sugar cane arrow during transport. So far it has been possible to preserve pollen in this manner for about ten days.

A striking use of this method in a rather difficult cross-pollination is described below. It was desired to effect a cross between *Saccharum spontaneum* as mother and a tropical cane "Karun" as father; but this was rendered difficult from the fact that the anthers of the former open much earlier than those of the latter, the approximate timings being respectively 6 a. m. and 8:30 a. m. By preserving the arrows of "Karun" in a special crate the above cross has since been successfully accomplished. The resultant seedlings now growing at the station show, in some of them, unmistakable traces of Karun blood.

Test for Pistil Fertility[6]

For a long time past the presence of starch inside the cells of the style branches has been used as a sign of pistil fertility. The test has enabled the raising of crossed seedlings with a high degree of certainty as to results. Other workers, however, have not found the test quite reliable. The correlation was, therefore, reexamined within the last two years, over 300 varieties and seedlings being subjected to the test. It has been found that, wheras it is a test of considerable value in the Indian varieties, it does not work satisfactorily in the tropical canes and breaks down in the case of new seedlings. This is of some interest and needs further investigation.

Value of Special "Arrowing" Plots in Sugar Cane-Breeding

It has been found a great advantage to plant what in the station are termed "arrowing" plots for carrying on the cross-pollination work. These are special plots laid out away from the main fields and are sometimes situated under different conditions. They are also sown often at a different time from the main plots. Certain of the advantages derived from them are here mentioned. Firstly, as varieties differ considerably in their value as parents, the special plots enable the growing of a large number of plants of the most desirable parents. Secondly, canes intended for arrowing sometimes need a treatment different from that for the main plots. It has been found that a vigorous growth in the early stages followed by a check, induced at Coimbatore by special ill treatment of the plants, is conducive to arrowing; the special plots enable such treatment being given. Thirdly, varieties in such plots frequently arrow at a time slightly different from those in the main fields, undoubtedly due to the difference in treatment. The slight differences in time of arrowing have often materially helped in the cross-pollination work. Indeed it would appear profitable to plant the useful parents under as many conditions of soil and irrigation as may be available at any station.

Collection and Storage of Sugar Cane Arrows for Sowing

The best stage to collect arrows for sowing is when the florets begin to separate from the top branches and drop off. Even arrows collected at a stage

as immature as to have the anther protrusion still in progress from the bottom branches have been known to germinate from the top branches; such seedlings generally turned out to be weak and showed a high degree of mortality.

In an arrow the largest number of fertile seeds are generally found in the top two thirds. Should there be rain the arrows need to be collected some little time after to allow their drying; arrows containing moisture quickly develop fungoid growth on storage.

Immediately after collection the arrows are loosely packed in tissue paper with full details written on a label placed inside of the packet and on the outside of the paper wrapper. Only a few arrows—not more than ten—are placed in each packet; this is done to allow a good aeration. These packets are dried in the sun for a couple of days to eliminate any moisture in them.

The packets are then taken to a closed room and the fluff collected on a sheet of tissue paper spread on the ground, the dislodgment being facilitated by tapping the arrow or gently passing the fingers down the arrow. In this operation the arrows are held over the paper, bottom upwards. The collected fluff is again wrapped loosely in tissue paper and labelled as before. The packets are not to be stored in great heaps or inside closed receptacles; they need plenty of ventilation and are best spread out on tables. The stored packets need protection against rats and ants. These are generally sown about two weeks after collection and, though definite experiments have not been made, the impression has been formed that if sown immediately after collection, the seedlings exhibit a higher mortality.

Germination and the Early Stages of Growth[8]

Sowing and Germination: For sowing, shallow, circular, country earthenware pans—12″ across at top, 9″ at bottom and 6″ high—have been found satisfactory. Previous to sowing the pans are numbered with some waterproof paint. Suitable provision having been made for free drainage at bottom, the pans are filled with a mixture of equal parts of well rotted horse dung and sand. The fluff is now laid in an even thin layer on the surface and the first watering done from a garden rose held 3 feet above the pans. The force of the impact gathers round the tiny seeds a small amount of soil and this facilitates germination. The quantity of water employed should not be such as to form a pool in the pan, as it leads to the seeds all getting to one side and germination is affected. Immediately after sowing, the pans are arranged in groups—each group containing all the pans of a particular lot—and each group is separately labelled with details as to variety sown, date of sowing and other details. For this purpose paper labels first written in pencil or Indian ink and subsequently dipped in melted paraffin wax have been found useful; they are unaffected by the frequent *watering*.[9] Germinations have not been noticed earlier than three days from sowing; and pans not germinating within a fortnight have rarely been found to do so later.

Watering: At Coimbatore, it has been found necessary to water the pans as often as three to four times during the day. The watering is always done through a garden rose. For proper germination it has been found necessary

to keep the fluff always moist. After germination the plants need much less water, as the roots quickly develop and traverse a good bit of soil. The young cane plants are often very susceptible to excess of water and quickly turn yellow.

Precautions During Early Stages: It has been found useful to place the seedling pans on raised bamboo platforms about 2½ to 3 feet from the ground. Besides facilitating constant inspection of the young plants the arrangement is of use against ants and crickets. It has been found best to place the seedlings in full sun. The young sugar cane plants appear to revel in full sun and are rather susceptible to any kind of shade. In one instance the circular shade from a coconut crown marked off a corresponding circle of weak and unhealthy plants in the pans placed under it.

Weeding and Thinning of Sown Pans: The appearance of a large number of grass seedlings, which in the earlier stages look much like those of the cane and hence are difficult to weed out, is a trouble of some importance. At Coimbatore, the two weeds chiefly met with in the pans are *Chloris barbata* and *Cynodon dactylon.* It was found that the number of these could be greatly minimized if the horse dung, which is apparently the chief source of infection, is pitted for a couple of months before use and periodically watered. The heat generated in the pits appears to cause the death of the grass seeds. As an additional precaution the filled pans are allowed to remain unsown from ten to twelve days and occasionally watered during the period. The grass seedlings that come up are pulled out and the pans are now ready for sugar cane growing. The very few grass seedlings that appear even after the above precautions are easily removed by trained laborers. Should the pans be found very crowded, and contain say more than two or three hundred seedlings, they need pricking after a fortnight into a second set of pans. If the germination is thinner the pans may be left till they are ready for planting in the first ground nursery.

The First Ground Nursery: Fields with a fair admixture of sand are chosen for this as well as for the second ground nursery. They are prepared as for an ordinary cane crop, except that the surface needs to be cultivated with extra care to secure a fine tilth. Raised beds are formed, each bed being two feet broad, four inches high and any convenient length, the last depending on the lay of the land. The beds are spaced two feet apart, the soil between adjacent beds being used for raising them. The space between the beds facilitates constant inspection of the young plants.

Seedlings are transplanted to this nursery after they have been a month in the earthenware pans and, as far as possible, with a little ball of earth round the roots. The seedlings are planted out in rows running along the breadth of the beds with a spacing of two and a half inches between rows and one inch between plants in the row. For marking the positions of the plants a bamboo framework with nails driven in at suitable distances has been found useful. The beds are watered immediately before and after the transplanting, the former to receive the seedlings and the latter to compact the soil round the roots.

Watering of the beds is done with a garden rose till the seedlings are well established, when irrigation from channels laid in between the beds can be started. It is desirable, however, to postpone the latter kind of irrigation till

the plants are strongly rooted. Seedlings that may get slightly dislodged during the waterings should be carefully placed in position and the soil round them compacted; this is necessary chiefly soon after the transplating.

When the seedlings are grown about four inches, a combined hoeing and earthing is given by drawing firmly a sharp piece of bamboo in between the rows. With this operation the soil automatically heaps itself a little on both sides of the seedling rows. No shade is raised over the plants. The plants are allowed to grow in this first ground nursery for about two months when they would be found to have grown to about nine to twelve inches. While planting into this nursery no selection is made; only the dead and the very meagre plants are left behind in the pans.

The Second Ground Nursery: Land for this nursery is prepared in the same manner as for the first. It is then marked into plots, each plot being ten feet wide and of any convenient length. Drains, irrigation channels and paths are formed as indicated in the plan. Each plot has an irrigation channel on one side of it and a drain on the other. Each drain serves the two plots on either side of it and the irrigation channel between two adjacent plots is separated by a path.

The plants in the first nursery are prepared for transplanting into the second by a rather drastic trimming of the leaves to compensate for the loss of roots during the uprooting and the transplating operations. With the help of a hand hoe shallow V-shaped grooves are cut into the ground along the width of the plots at a distance of eighteen inches from one another. The prepared plants with balls of earth round the roots, are placed in these grooves, six inches apart and slightly watered. The removal of plants from the first nursery with balls of earth round the roots is greatly facilitated by the condition of soil in that nursery and by the fact that the plants are in beds raised from the ground level; the latter easily enables an operator to work round the plants. The plants are placed in position in the rows by raising a ridge of soil all along the row. Immediately after the ridging a copious irrigation is given to the plot.

For satisfactory results it is essential that the irrigation in the second nursery should be gentle, copious and of a soaking nature. This is secured by irrigating at the same time ten to twelve rows in the plot and by handling more than one plot at the same time. Water is led into the irrigation channel of the plot right to the farthest and lowest end. As there are no bunds separating the irrigation channel from the trenches between the rows of canes water would first fill in the end rows. When ten to twelve rows are thus irrigated, a bund is placed across the channel and a second set of ten to twelve rows receive the water. These rapidly fill in when a second bund is placed across the channel and water turned onto a third set of rows. A plan is given indicating the manner in which the irrigation is done. In this irrigation, irrigation water never touches the stems or leaves of the seedlings as they are situated on raised ridges. The drain in between the plots is of considerable use for drawing off any excess of water in the trenches after rains or an irrigation. The irrigation above described consumes a fairly large amount of water but it appears to be necessary for a satisfactory and uniform growth of plants in the second nursery. At Coimbatore such irrigations are given about once a week.

No shade is raised over the seedlings in the second nursery; any shading only prolongs the life of the weaklings. When planting from the first to the second nursery no special elimination is attempted. It would appear to be rather risky to attempt any eliminations before the full growth in the second nursery; certain seedlings which were rather poorly in the first nursery have suddenly bucked up in the second and have since proved useful in the districts. Such sudden progress in growth of seedlings is often associated with a sudden and rapid multiplication of the roots at the time

Trouble from white ants is sometimes experienced in the first and the second nurseries. Use of partially decomposed manure, often containing half decomposed fibrous material, is a great attraction for the pest. Tar-emulsion has been found of use in fighting it. The emulsion is prepared by dissolving a pound of soap in the same weight of water, boiling it and adding gradually about a pound of coal-tar during the boiling. The emulsion can be kept for sometime and, when needed, is diluted with water to make a half to one per cent solution. One per cent solution of this emulsion kills soft leaved delicate weeds. The solution is applied to the trenches from a garden rose before an irrigation. The irrigation water as it sinks down carries the solution along with it and helps to keep out the pest. Another common pest is the shoot borer *Diatraea auricilia* and no satisfactory remedy has yet been found for this.

Plots for Testing

From the second nursery the seedlings go to the final plots for testing. Here they are grown for well over a year and their botanical, agricultural and chemical characters studied all through the period. It is only at the time of planting in the final plots that any real selection of the seedlings is practiced. The selection is made on a large number of characters, vigor, habit and tillering being the more important of them. Some idea of the extent to which natural and artificial eliminations are made from germination to final planting would be gained from the numbers for the 1923-24 batch of seedlings. Out of one lakh and thirty thousand seedlings that germinated about a lakh were planted in the first nursery; eighty thousand of them reached the second nursery and in the final plots it is expected to plant out about ten thousand for the full year test.

The planting in the final plots differs from the others in one important respect. Whereas in the latter the seedlings are moved more or less intact, the final plots are planted from sets obtained from the seedlings. The nearly six-month growth in the second nursery is generally sufficient for cane formation in the seedlings; seedlings that do not form canes within the period are, it is believed, not likely to be of use for the bulk of North India with its short growing season. The immaturity of the sets at time of planting does not appear to be any disadvantage. On the other hand, they germinate very readily and very few gaps are noticed in the final plots. There is yet another advantage in planting the final plots from sets instead of with the seedlings themselves. When, in the earlier years, the seedlings were transferred to the final plots almost intact it was noticed that they exhibited a rather abnormal vigor, i. e., a vigor not always maintained

when the seedlings were multiplied from sets later on. With set planting a more dependable vigor is available for observation at the time of selections. The importance of this will be realized when it is remembered that the subsequent multiplication of useful seedlings is entirely from sets.

The period from germination to final planting occupies about nine months. The cane arrowing season at Coimbatore is October-November. By beginning of January the seedlings would be germinating. They are moved into the first nursery January-February and into the second April-May. They grow in the second nursery till August-September when they are ready for planting into the final plot. They remain in these plots well over a year, i. e., till past next September. Coimbatore possesses two seasons for the planting of canes; one in wet lands about February and the second in garden lands July-August. The planting in the final plots is done about September, towards the end of the second planting season at Coimbatore.

The testing plots are planted as indicated in the plan. The seedlings are arranged in square blocks of one hundred and the parents, the grandparents and sometimes the standard canes also are planted at the extreme sides of the plots. Whenever the seedlings are studied or their juice chemically analyzed, the parents and others are also dealt with at the same time. As the main object of breeding is to obtain types which are definite improvement on the parents or the standard canes, the advantage of having them always near and growing under practically identical conditions is obvious. The manner in which the seedlings are numbered in the plots is indicated in the plan.

It was frequently noticed that the border plants of a cane plot—those adjoining a path, an irrigation channel or a drain—showed markedly greater vigor than those inside the plots. At the time of selection it was found difficult to decide, in the case of a border plant, how much of its vigor was due to its advantageous position in the matter of light, air and water. To render the conditions of growths in the plots more uniform the borders are planted with a row of some fodder grass or a standard cane. This is cut out immediately before the plot is taken up for the final studies with a view to selection.

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Entomological Work in South America
September, 1922 - July, 1924

By Francis X. Williams

Object of the Work

The main purpose of the work was to secure natural enemies of the wire-worms, *Monocrepidius exsul* and *Simodactylus cinnamomeus*, that cause damage in some of the Hawaiian cane fields. Search was also made for further parasites which might attack the cane beetle-borer *Rhabdocnemis obscura,* and for such other beneficial insects as opportunity offered. In addition, some effort was made to collect seeds of trees which would be of use for reforestation purposes in Hawaii.

Countries Visited

Nearly nine months were spent in Ecuador exploring regions both east and west of the Andes, five months in British Guiana, and six months in Brazil. Furthermore, brief stoppages were incident to the journey at the transshipment points, Panama, Trinidad and Barbados.

Itinerary and Investigations

On April 28, 1922, I returned from the Philippines, and on June 17, sailed for San Francisco. Following a vacation of some weeks in California I left for the East and after an interrupted trip arrived at Washington, D. C., on August 10. I remained there until August 30, employing my time mainly in the U. S. National Museum, looking over some of their extensive collections of Aculeate Hymenoptera and familiarizing myself with the larger Bethylid wasps, one species of which in the United States is known to prey upon the larva of a wireworm allied to our Hawaiian *Monocrepidius exsul.*

At the U. S. National Museum, as elsewhere throughout my travels, assistance in every way possible was extended me, and thanks are due to many individuals and institutions.

I embarked September 2, from New York for the Canal Zone on the United Fruit Company S. S. *Toloa.* After a layover of three days at Havana, Cuba, we

proceeded westward, reaching Cristobal, Panama, on the morning of September 12. At Ancon, on the Pacific side of the Isthmus, I met the U. S. Government Entomologist, Dr. James Zetek, and Mr. Molino, his assistant. On September 21, I left Panama for Ecuador on the Peruvian steamer *Mantaro,* which stopped for some hours at Buenaventura, on the Colombian coast and continuing the journey southward arrived at Guayaquil on September 26. This city has in the neighborhood of 90,000 inhabitants and is not, properly speaking, on the seacoast; to reach it one must travel miles up the extensive Gulf of Guayaquil and for a short distance along the Guayas River. Opposite the city this river is over a mile in width, though soon breaking up into several tributaries derived chiefly from the Andes, whose western crest is less than 100 miles distant. The more brackish lower part of the Guayas River is noted for its fine large "mangles" or Mangrove

Balsa trees near Bucay, Ecuador. The wood is lighter than cork and much used in making rafts or "balsas."

trees, straight logs of which may be as much as fifty feet long, while in contrast to this heavy wood are rafts made of the lighter-than-cork "Balsa" tree, which flourishes a short distance inland and not infrequently yields sixty-foot timber. The chief product of Ecuador is cacao, with the ivory-nut for making buttons, etc., and fine hats, wrongly called "Panama" hats, holding an important place. Sugar is not manufactured in exportable quantities. Tobacco and rum are of some consequence.

Guayaquil is no longer a hotbed of yellow fever, but a healthy city. Rats are not encouraged in the municipality; the rat catcher may frequently be seen issuing from a building carrying his more or less filled wire traps, or some defunct rodents to the well-laden burro waiting outside. The garbage department as in many other places in tropical America, still has the assistance of numerous "Gallinazos," or black-headed vultures.

Forest during the dry season near Guayaquil, Ecuador. Conspicuous in this now comparatively leafless wood are leguminous and bignomiaceous trees. The seasonal aridity of the district is due in great measure to the proximity of the antarctic current, which so cools the atmosphere that it cannot condense over the hot lowlands.

I reached Guayaquil in the midst of the dry season, which though by no means universal throughout Ecuador is very marked about the city. The rains commencing suddenly in December convert the parched hills of mainly deciduous trees into masses of tropical verdure; and furthermore, they coax out of concealment innumerable "Grillos" or crickets into such conspicuous activity as to become a perfect plague for a few days, invading dining room and bedroom alike, alighting upon the headgear and shoulders of pedestrians, furnishing effective missiles for street gamins, and so flooding the brightly illuminated plazas that they must be swept up in heaps on the following morning. By the end of June dry conditions again prevail. Some little distance inland, however, the country is moister at any season; this is true at 90 kilometers, or about 56 miles along the Guayaquil and Quito Railroad, where the elevation is 1,000 feet. Ten kilometers farther the altitude is 1,850 feet, while beyond this the ascent of the Cordillera commences in earnest, for at Huigra at kilometer 117, amid stupendous fog-topped cliffs the altitude is 4,000 feet, though dryer conditions, emphasized by the presence of several species of cacti, spiny leguminous shrubs, and grasses, are evident. The Andes, at least in this part of Ecuador, are not well wooded for

their upper portions, as frequently is the case to the contrary in other countries of high mountains. On the lofty plateaux or higher mountain slopes the various herbs and shrubs often display handsome flowers. The paramo (11,000 feet up), a sort of upland desert, is characterized by certain plants, among which are curious compositae of gregarious habit, and by dreary areas of grass, or "pajonales." Finally the vegetation ceases and we may have exposed sand and cinders ("Arenales") up to the limits of perpetual snow, which in Ecuador is rather over 15,000 feet above sea level. There are sixteen or more perpetually snow-covered peaks in this country, the loftiest being Chimborazo, 20,496 feet, and Cotopaxi, 19,614 feet, usually considered the highest active volcano in the world.

The sugar cane industry in Ecuador is still in a very undeveloped condition. While there are several tolerably large plantations with mills for the manufacture of sugar, the more usual, small scattered areas planted to sugar cane are devoted very largely to the production of rum or "aguardiente," which potent beverage finds a ready sale, chiefly among the lower classes and the indigenes. In some instances, these rum factories appear tolerably up-to-date, with a water wheel for operating the mill, or oxen may be used for this purpose; in still other cases the affair may be simplicity itself—housed under a palm-thatched shed in the primeval forest, two hardwood logs serving as rollers and turned by means of wooden spokes (2 man power), a wooden catch-bowl beneath, and to one side, the distillery, consisting of a hollowed-out log with the necessarily tightly fitting cover, a sheet of crushed cane stems.

Considerable travel in sugar cane and other districts was done in Ecuador, and for making possible or facilitating these journeys, thanks are due to several gentlemen and particularly to the American Consul at Guayaquil, Dr. F. W. Goding, himself an enthusiastic entomologist. My first sugar cane pest investigations were made late in September at Ingenio Valdez, Milagro. This sugar estate, which is the most advanced in the country, is about an hour's train ride from Duran, across the river from Guayaquil. The mill is equipped with centrifugals and is fed from the cane fields by a plantation railroad. The extensive flat lands are planted chiefly to two varieties of cane, D 74, said to have been brought over from Louisiana, and "Nacional." The latter is a cane of nice appearance and whose tolerably soft stems are yellowish green and of good sugar content. It ratoons well and one is impressed by the large number of stems per stool and the well-developed root system. Harvesting was going on at the time, when a type of Louisiana cane loader was in action.

After the fields are cropped, the trash is disposed of by fire with the effect of driving out some of the fauna, consisting of lizards, rats and so forth, and which are forthwith attacked by the large birds of prey, constantly in the offing. The so-called Caracara "eagle" of ready cursorial ability as well as being a good flyer is one of the foremost of these feathered predators.

I recognized no cane diseases at Milagro, though not a few of the stems had split open disclosing the reddened interior. The most obvious sugar cane insects encountered here, as nearly everywhere else in cane countries of South America, were borers, of which a moth (*Diatraea?* sp.) and a weevil (*Metamasius*) were doing considerable damage. Of fifty harvested cane stems examined 74 per cent

showed borer injury. The young cane was at times badly damaged, presumably by the same moth larva, which killed the central shoot. A small weevil found as a larva and pupa worked rather close to the rind, but was not plentiful. Of leafminers, the larva of a small moth tunnelled near the leaf's edge. It was infrequent and was parasitized by a small wasp. Among insects with sucking mouth parts was a diaspine scale insect and the usual mealybug, besides a sparse and rather large Fulgorid leafhopper (*Bledina*). The ground was dry and hard and no wireworms were unearthed.

Bucay, my next stop inland, some fifty miles from Guayaquil, was visited October 4-11, 1922, and again June 2-5, 1923. I was put up at the house of the manager of the two rum factories; in one of these the crushing is done by a water wheel, in the other by oxen. The larger factory disgorges its fire-water into receptacles at the railroad by means of a pipe line several hundreds of feet in length. The sugar cane, which is of several varieties, is little attended to, apart from the replacing of gaps in its rows.

Insects are always abundant at Bucay since the moisture is usually sufficient to sustain them, and one notices the greater variety of butterflies as compared with those of some of the regions of the Far East. There was no difficulty in digging up several species of Elaterid wireworms in certain cane fields and in the grass lands adjoining, but none of their parasites was found. The beetles were likewise abundant and I saw here for the first time the brilliantly luminous "Cucuyo" beetle (*Pyrophorus* sp.), an insect allied to, though larger than *Monocrepidius* of Hawaii. Children strive to attract these "Cucuyos" by whistling, and waving a firebrand at them. What are known as false wireworms, and belonging to the beetle family Tenebrionidae could be scraped up under debris, such as flattened and decayed grass, and one of these larvae was found with a wasp grub on its underside, doubtless the young of one of the Bethylid wasps not uncommon about the cane fields. A common Bethylidae with a red-tipped abdomen was tried on true wireworms, but would not attack them. White grubs were not found in troublesome numbers, and one which was unearthed proved to be parasitized by a wasp grub, probably that of a *Tiphia,* clinging to the back of the second and third segments of the thorax. The cane stems were bored by a weevil larva, as at Milagro, but the insect was far more abundant in defunct banana stems nearby. The sugar cane mealybug found in one patch of cane was preyed upon by two species of ladybeetles (Coccinellidae). The larva of the rarer of the two was covered with waxy white processes, while that of the commoner was naked brown. Froghoppers or spittle insects (Cercopidae) of one species were not infrequent, breeding on the sugar cane stems. Only the young are enveloped in a frothy white mass in among the leaves, or between a leaf and the stem. The adults sometimes two or three per stem, were well wedged in at leaf bases. What seems to be the more injurious species of these insects, however, as occur in Trinidad, parts of Brazil, and in other places, feed, at least as young, largely on the superficial roots of the plant. Many leafhoppers were seen resting in weedy cane, though none seemed definitely attached to it.

Sucking at decaying cane stubs one occasionally flushes the very brilliantly metallic blue *Morpho,* an insect of considerable expanse of wing, and probably the most vivid and popularly known butterfly of tropical America. The wings

of these insects are much employed in decorative art, such as in glass-bottom trays, etc.

I found red mites or spiders attached to many kinds of insects in Ecuador and in greater numbers than observed elsewhere. This is true also of certain entomophagous fungi in the Neotropics, many *Cordyceps* (?) species developing fantastically on wasps, beetles, moths, leafhoppers, caterpillars and other forms.

The next move was to Naranjapata 100 kilometers along the Guayaquil and Quito Railroad, the place being marked by the railway station, a few laborers' cabins and a water tank. Entertainment was furnished after bedtime in the station master's office by the antics along the walls and ceiling, of the numerous white-bellied rats. At Naranjapata, as at Bucay, are banana plantations which have an interesting though unwelcome insect fauna. First of all, a huge, dark colored moth of the family Castniidae, in the larval stages attacks the stem of the plant, and judging from the size of the boring caterpillar one might well suffice to destroy a small plant. A second and smaller species, the widely distributed *Castnia licus,* also attacks the banana stem as well as that of the sugar cane. Orchids also suffer from the larvae of Castniidae. Dead or unhealthy banana plants are infested by the cane beetle borer of the region and by what seems to be another though closely related species, which tunneling often very profoundly into the watery pulp appears free from parasites, although preyed upon to some extent by the larva of a histerid beetle, itself not adverse to the semi-aquatic conditions of the stem. A fine butterfly, *Caligo* species, with a wing expanse of 6 to 8 inches, produces a docile brown larva several inches long that feeds on the banana leaf. Other species of *Caligo* sometimes attack sugar cane; a smaller yet still rather large butterfly, *Opsiphanes* by name, is also a banana

A portion of the village of Baños at 6,000 feet in the Ecuadorean Andes. In the left foreground is a patch of sugar cane; behind and above it on the hillside a 300-foot waterfall; to the right is Badcum Valley, with the cloud-wrapped Tunguragua volcano at its head. The tall and very slender trees chiefly to the right are native willows and a species of poplar.

feeder. At least *Caligo,* and probably *Opsiphanes,* are nocturnal or nearly so. The larva of a small bagworm moth with its mealy white banjo-shaped case is not uncommon on the plant and appears to feed on the fine powdery bloom of the stem and leaves.

Towards the end of my stay in Ecuador, a few days (May 30-June 2, 1923) were spent at Huigra at 4000 feet on the Pacific side of the mountain slopes. Nothing of note was found there.

Over a month—in two installments (October 25-November 5, 1922 and December 27, 1922-January 22, 1923) was passed at Baños, high up upon the eastern shoulder of the Andes. This interesting old village is situated upon an ancient lava deposit in the narrow valley of the Rio Pastasa, a wild and dangerous stream that finally works its way into the upper Amazon. The elevation is here about 6,000 feet and one has but to wander to the edge of town to view the fine snow-covered Tunguragua volcano rising to a height of between 16,000 and 17,000 feet. This mountain, which is still smoking, and occasionally, it is said, emits loud noises, has more than once devastated the region about its base. The vegetation upon its higher slopes is clothed, often densely, with fine ash. The Baños region is of wonderful scenic beauty with its 300-foot waterfall, towering mountains and the cleft-like Pastasa gorge. There are hot springs and a mineral spring in the village itself. Fairly comfortable quarters were secured in one of the few second-story houses of the village, while tolerable meals were doled out at the "Agencia Funeraria," the coffin shop being next the dining room. The district can scarcely be called tropical although it suddenly becomes so only a few miles to the eastward. Baños bananas are comparatively expensive and of poor quality, but the sugar cane plants, sometimes growing alongside of wheat or barley, have a better appearance than one would expect for so high an altitude. No particular variety

The Baños Rum Brigade climbing the Andes. The often unassuring bridges spanning these mountain gorges are braced and supported by steel rails.

of sugar cane is planted here; some of it was seen in tassel. The stems may be dark, striped or concolorous and one kind, grown on a very small scale, was nearly entirely purplish, leaves and all. The villagers go to some pains in raising cane, and nicely erect stalks stripped of the lower leaves were noted. The rum factory is operated in part by the abundant water power available in this rugged spot.

No sugar cane diseases were recognized. Of insect enemies the following came to notice: A *Diatraea* (?) moth borer; a leafminer, perhaps the same as occurs at Milagro; the larva of a skipper butterfly, devouring the leaves, as well as some leaf-feeding beetles (Chrysomelidae); the latter, though abundant, did not seem habitual on the plant; several species of leafhoppers, some being Delphacidae; and a froghopper or spittle insect (Cercopidae). The leafhoppers were not found breeding on the plants, as was the case to the contrary with the froghoppers on the shoots and stems, though this insect did not appear of major importance. Mole crickets were plentiful in certain cane fields. White grubs were abundant in grass lands, and their wasp enemy, *Tiphia* also present, as well as a huge *Scoliid* species.

Considerable digging, mainly in cane fields revealed several species of true wireworms as well as wireworm-like larvae. Here, as elsewhere in localities visited, wireworms of the *Monocrepidius* type generally prevailed over the slenderer forms. Among the species dug up were luminous examples of rather large size, presumably the larva of the "Cucuyo", *Pyrophorus* species. Another type though hardly a wireworm was the brilliantly lit up and very active larva of a *Phengodes* (?) beetle, an insect more related to the true "fireflies" (Lampyridae). An hour's digging for wireworms resulted as follows:

	Larvae	Pupae
Monocrepidius-like	10	2
" " but darker	5	0
Slenderer form	1	1
Phengodes	1	0
Wireworm-like larva	5	6
	22	9

Nothing was found attacking wireworms.

In hopes of meeting with better success farther within the luxuriant Oriente or eastern province of Ecuador, I left Baños for Tena near the Napo River, on January 22, 1923. As one descends into the Amazon basin the granite or granite-like rock of the mountains becomes more and more overlaid with soil, in many places turning into a morass, so that at Mera, some thirty miles away one finds himself at 4000 feet elevation, in an exceedingly verdant and watery region, so much so that the numerous slender palms have adapted *Pandanus*-like prop roots to better sustain themselves in the uncertain earth, and water bugs seem to consider the contents of the veriest hoof prints a permanent body of water. Here at the village of a very few, scattered, palm-thatched houses might be seen a domestic fowl knee- (or heel-) deep in a rain puddle scratching away and gobbling up any morsels that rise to the surface. It was noticed here that quantities of Guinea pigs are kept in the kitchens, to be served from time to time at meals. Mera is a mere notch in the wilderness, the Pastasa River at the base of the tall

This illustration shows the basal part of a feather palm in a clearing in the rain forest of eastern Ecuador. The plant has prop roots much recalling those of the Pandanus and which better sustain its slender height in the boggy soil. These palms are very useful; the central shoot furnishes an appetizing dish, the leaves thatching, while the stems when split open, cleaned out and unrolled, make good flooring and walls. Such palms, though only eight or nine inches in diameter just above the prop root system, not infrequently attain a height of a hundred feet or more.

bluff which skirts the settlement at the right, the soggy forest filling in the rest. The minute patches of sugar cane contained a species of stem froghopper and moth borers, while the felled and decaying palm trunks quickly attracted *Metamasius* weevils. The Mera cane is superior to that at Baños.

A more or less bog-strewn journey of several days, a short canoe ride down the Anso and the Napo rivers to the tiny village of Napo, with a very muddy stretch of five or six miles brings one to Tena, a pleasantly situated place of some forty inhabitants. While quite tropical, its altitude of nearly two thousand feet produces an agreeable climate. It is a healthy if depressing place. Bread and regular potatoes are almost unknown and molasses largely substitutes for sugar. The cane as usual, is cultivated chiefly for rum purposes; some of the plants were tall, stout-stemmed and of fine appearance. One erect variety springing from rather massive stools and with a bloom on the stem somewhat as in our H 109, attained a height just before tasseling, up to about 18 feet, with bare stem to 10 feet. These were more than a year old, however.

Sugar cane at Tena, in eastern Ecuador.

What appeared to be mosaic disease was prevalent on some weedy cane. Of noxious insects pertaining to this plant were the usual South American types. Two species of stem froghoppers (Cercopidae) were found, but one was not very exclusive on the plant. The leaves were eaten by the larva of a noctuid moth, and a borer, probably of the same family, affected the stems. *Metamasius*

weevils, insects allied to the cane beetle borer of Hawaii and farther east, were very numerous, the adults occurring on pineapples, araceous plants, *Inga* (Leguminosae) pods, banana and palm stems and sugar cane and breeding in the last three plants and badly damaging the cane. *Castnia licus,* a giant moth borer is occasional in cane and banana plants. The large juicy whitish caterpillar is eaten with gusto—as are many other, not altogether pleasing-looking insects, and the huge land snails—by the ever-hungry Indians of the region. Occurring sparsely as a cane leafminer is the larva of a Chrysomelid beetle. The presence of small ladybeetles (Coccinellidae) in cane fields would indicate some Aphid or mealybug pest there. No cane mealybugs were found, however, a small species feeding underground at the base of the stem of bananas is preyed upon by a little Coccinellid.

Tena was not a promising locality for wireworms. A quite large predaceous species was occasionally met with under the bark of a dead tree, and adults of smaller species were also collected.

Of pests of man and other animals, mosquitoes were usually not troublesome save in certain forest districts; buffalo-gnats (Simulidae) were common in the vicinity of some of the rivers and at times quite annoying; in fact, I noted that the backs of my Indian carriers were more or less closely stippled with the bites of these insects. The ordinary house-fly (*Musca domestica*) which swarms on the inter-andine plateau, and where it may sometimes be seen nearly concealing by its numbers the otherwise luscious-appearing strawberries sold by the Indian women at the railway stations, seemed exceedingly scarce about Tena. The vampire, a small, plain looking bat sometimes attacks man exhibiting, they say, a fondness for feeding at the big toe, or turning its attention to one's rostrum; the shoulders or the necks of horses and cattle not infrequently show dried drops of blood, the result of small wounds made by these creatures.

Plans having miscarried for the proposed trip down the Amazon, I retraced the hundred-mile journey to the city of Ambato on the highlands. Arriving in Guayaquil in the middle of May, 1923, to set sail therefrom on June 13, for British Guiana, via Panama, north coast ports of Colombia, Venezuela and Trinidad. Sailing first on the Chilean steamer "Palena", the journey was continued from Cristobal to Trinidad on the French liner "Pellerin de Latouche". We arrived at Port of Spain, Trinidad, June 30, but no steamer to British Guiana was available until July 10.

Trinidad is about half the size of the island of Hawaii and is the southernmost of the West Indies, being but a few miles distant from the Venezuelan coast. It is well forested and traversed by several mountain ranges. Among its chief products are sugar, cacao, copra and Angostura bitters, as well as asphalt from the far-famed "Pitch Lake", which covers an area of one hundred acres. Chiefly through the kindly offices of Mr. F. W. Urich, Government Entomologist, I was enabled to see something of the country and its agriculture and to become acquainted with some of the insects, both good and bad. Of canes, D 109 and B 156 are among the popular varieties. Uba cane, which resembles ours in Hawaii is planted locally, especially on the poorest lands where a hard-boiled variety does well enough and chokes out the weeds. It grows densely and a fire must be passed

through it before harvesting. Ninety-eight per cent white sugar is made in Trinidad, and in the one "factory" visited, both the maceration and the regular method of extracting the juice were used. One sugar estate at Caroni and another near San Fernando, as well as a couple of cacao plantations were visited. The sugar cane froghopper, *Tomaspis saccharina* was not bad at the time. Other pests are *Diatraea* and *Castnia licus* stem borers. A Chrysomelid beetle, *Myochrous armatus,* injures the cane leaves as does also the larva of one or more skipper butterflies (Hesperidae).

Wireworms as larvae and adults were not uncommon, but at least those related to our own *Monocrepidius* are here rather considered beneficial for their mainly carnivorous habits. They were dug out of old logs in cacao plantations and the beetles were also to be found among sugar cane. No insect enemies of wireworms were discovered, although a dead, lead colored Elaterid pupa taken out of an old log proved, on being opened, to be filled with a sort of round-worm (*Myrmis?*).

The mongoose seems generally not looked upon with favor in Trinidad, whose cane field and other faunae are such that they suffer much from the depredations of this animal. Birds and lizards are among the victims. Damage by rats does not appear to be very serious.

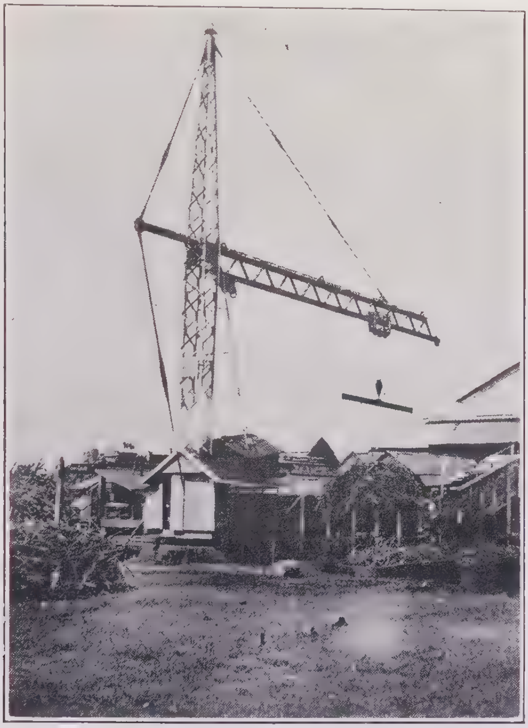
"Para" and "Kelley" grass are noxious plants. "Nutgrass" (*Cyperus rotundus*) occurs in Trinidad as also abundantly on the tropical mainland. It is attacked in the Neotropics by the boring caterpillar of a small moth.

There are some large cacao plantations; and many or most of them are shaded by "Immortels", a species of *Erythrina* tree. Windbreaks for these estates consist commonly of a plant appearing to be the same as or very close to our "Ti" plant, *Cordyline.* There is a coconut industry. The plantains are often badly attacked by the weevil *Cosmopolites sordidus.*

A journey of rather less than two days brings one to the low muddy coast of Demerara or British Guiana. Georgetown, the capital, is a city of about 60,000 and is situated at the mouth of the Demerara River. Demerara is also the name of one of the three counties of British Guiana, the other two are Essequilo and Berbice. The whole country lies between 0° and 9° north of the Equator. While the coast presents a rather uninviting appearance, the "hinterland" is magnificent, with its tall dense forests and rugged mountain range. Kaieteur Falls is a sheer drop of the Potàro River of 740 feet. Among the products of the country are cane sugar, Bauxite (Aluminum ore), gold, diamonds, "balata", which is the sap of a forest tree used for "belting and boot soles", and such fine timber as "greenheart" and "purpleheart." The soil of the front lands, as a rather narrow strip, is heavy "marine alluvium", with here and there a sand reef, and some peat-like material. So devoid of stones is this low area that baked earth is used in the construction of the coastal highways.

In Georgetown, the Department of Science and Agriculture and of the Lands and Mines, the Museum, and the Sugar Cane Experiment Station were several times visited. A short trip was made to the interior via the Demerara, Essequibo and Potaro rivers to Tumatumari on the Potaro River. Otherwise, the time was employed on and about sugar estates. These are all on or very near the coast,

which being below the level of high tide is protected by a great sea-wall provided with numerous sluice gates or "kokers" that at low tide release the pent-up fresh water. The sugar plantations are laid out in quadrangles, the boundaries being canals, of which there is also an extensive and well distributed system in these quadrangles, and serving as transportation or as drainage ways. Large animal-



Loading cane onto the carrier from punts. Berbice, British Guiana.

drawn punts of about 27 by 8 feet, with iron sides and "Mora" wood bottoms, and often in long trains, carry the cane from the harvested fields right up to the cane loader of the factory. Thus also to a large extent are the plows and caterpillars borne afield, for mechanical tillage has been going on here for some years. This sort of cultivation is feasible only in new lands, or in old fields where the ditches have been filled up to allow the passage of the 50 h.p. caterpillars and their plows. Ordinary forking by the task is the usual form of cultivation in the fields that do not permit plowing. The labor is chiefly East Indian. Bourbon cane was once extensively grown in British Guiana but eventually, as in some other countries, it ceased to be productive and is now replaced by other varieties, chief of which is D 625 produced through the efforts of Sir J. B. Harrison, Director of Science and Agriculture, and his associates. D 625 is a hardy yellow cane that resists drought well. It seems that here ratoon crops rather than those from plant cane yield the heaviest tonnage.

Newly planted cane in Berbice, British Guiana. The cane soon "peeps up" and each little shoot gives rise to five or six "pickaninnies." Note that the East Indian "driver" or overseer carries with him a brush for combatting mosquitoes.

The greater part of the time spent in British Guiana was at Plantation Blairmont, a few miles up the Berbice River and directly opposite New Amsterdam, the second city of the country. Here good laboratory facilities were available, and I am indebted to the officers of this estate, especially to Mr. H. E. Box, the Blairmont Plantation entomologist, as well as to Mr. W. H. B. Moore, the Albion Plantation entomologist, to Mr. L. D. Cleare, government entomologist, and to many others.

No mosaic disease was found either in Trinidad or in British Guiana. In the latter country a disease commonly referred to as *Marasmius* was not uncommon in certain cane fields, and was characterized, in gross fashion, by the affected plants turning brown as if burned, by a basal mycelium developing to mat the sheath trash against the cane stem, and by the stool pulling up very readily.

A little of the sugar cane entomology as well as other entomological data are set down in my notes of August 23, from a visit to one of the plantations. "In the afternoon we took a 50 minute mule-drawn bateau ride in one of the canals to where the 'borer gang' was working. This field was in very young plant cane, much of it drowned out by floods. The old 'banks,' i. e., the ridges

(at present) between rows and on which the old discarded ratoons were thrown to make room for the plant cane, had stools ratooning freely, so that this cane stand—not destroyed because of the shortage of labor—was taller and, in places, denser than that of the soggy seed cane, and furnished at the same time 'suckers' for 'supplying' (replanting) and a holdover place for borers. These borers were mainly the red-headed larva of the moth, *Diatraea canella,* and were being cut out by young coolies. The work is not arduous, for only growing shoots are operated upon, the 'dead hearts' locating the damage. In a badly infested field as in the one being considered, the worker need move but very little during the whole day, as sufficient material is close at hand. The infested shoot is cut sufficiently low, then shaved off until the borer is exposed when a few jarring taps with the knife partly dislodges it from the tunnel, to be seized and placed in a round tobacco box, whose base or lid the worker often hammers out into a bulge to enlarge its capacity. The catch eventually becomes a tightly packed mass of *Diatraea* larvae, with an occasional weevil borer (*Metamasius*) and more seldom still, a large larva of *Castnia licus,* the giant moth borer. The pay for *Diatraea* larvae and pupae on this plantation is four pence a hundred. Record catches mount up to 1000 borers per day, so that children may sometimes make more money in a day than do their parents engaged in other plantation work. The borer-gang may consist of more than 100 individuals. *Diatraea* parasites found during this work are reared in a laboratory and liberated. *Ipobracon,* other braconid wasps and a fly attack the larva. The moth lays her eggs in a patch on the cane leaves. A minute wasp, *Trichogramma,* may parasitize the entire egg-mass, when it assumes a blackish color. Another egg wasp, *Prophanurus alecto* seems less efficient. As we proceeded up the canal I swung my net along the little grass islands, and thus bagged numerous little flies and leafhoppers. Farther along, the nests of hornets (*Marabuntas*) of the genus *Polistes* were numerous on the canal's side boards, so that for a short space it was advisable to release the scraping towing line and resort to paddling. While hardly a cane pest, alligators are common in the trenches and are said sometimes to lay their eggs in the fields, and to furiously pursue anyone approaching the nest. I was told of and saw the 'yellowtail,' a large black snake, with a yellow tail that frequents the cane fields of British Guiana and is reckoned a very efficient rat catcher.

As we passed along the canal, for about a third to a half mile, lay heaps of burning termite nests, the dark, firm, ball-like structures certainly totalling far into the hundreds, if not thousands. These nests are collected from the cane fields where they are often attached to cane stalks, which the insects may damage considerably.

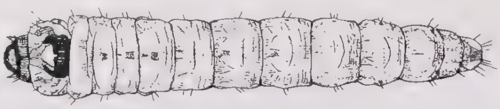
Mr. Moore showed me a very small bug living upon the surface of the trench water and most useful in destroying mosquito larvae, one jab of the beak being fatal to its prey. Mosquitoes are certainly surpassingly numerous at certain times of the year in many places along these 'front lands.'"

There are three species of *Diatraea* moth-borers, *D. canella, D. saccharalis* and *D. lineola* in British Guiana, the first two are the most serious cane pests, the last seems rather inconsequential. When full fed their slender larva is in

the neighborhood of an inch long. In addition to destroying the young shoots, the old joints are likewise attacked, and very frequently so many "eyes" or buds are eaten out of the seed pieces as to necessitate considerable replanting, or "supplying" as it is here termed. The borer also has the habit of working around within the comparatively soft root band so that the cane often breaks at that point from sheer weight, or because of the wind. The ubiquitous "razor" grass (Graminiae) as well as some other grasses are also *Diatraea* host-plants. The large conspicuous inflorescence of "razor" grass is very attractive to several species of wasp parasites of *Diatraea,* so that one may find numerous examples of an *Ipobracon* (?) upon them even to the exclusion of other insects.

It has been found by the government entomologist that immersing the "seed" cane in water for three days, destroys all the borers. At present, however, *Diatraea* is controlled neither by artificial nor natural agencies.

The giant moth borer, *Castnia licus* at one time was quite a serious pest and even now must be reckoned with. It has been found worth while to flood badly infested fields and thus destroy the borer, which usually restricts its activities to the lower part of the cane plant.



Castnia licus, full-grown larva from Tena, Ecuador. Slightly reduced.

Castnia licus, from Belen, Para. A moth native to tropical America, where its larva often bores the stems of sugar cane. X $\frac{4}{3}$

Following up mechanical injury, the damage caused by *Diatraea,* and infesting plant tops as well, is *Metamasius hemipterus,* a beetle borer related to *Rhabdocnemis obscura* of Hawaii and farther east, but differing from it among other things—in not primarily attacking healthy cane. The insect is abundant in some cane fields and seems to have no efficient enemy. There is a single record (Moore, 1915) of a wasp grub found feeding on a larva of this *Metamasius.* Later, by the aid of Mr. H. E. Box, I was enabled to examine over a thousand of the beetle grubs, with the result of finding a single very young wasp grub on a paralyzed larva; and in another case an adult *Ipobracon* (?) wasp (♂) just issued from a cocoon in a *Metamasius* burrow, the remains of the host being nearby. Examples of this species of wasp were subsequently taken on razor grass, but they could not be induced to do more than merely paralyze a few of the most advantageously exposed *Metamasius* larvae. From this experiment one might conclude that *Metamasius* is not the normal host of this wasp. Occasionally infesting cane stools is the larva of the palm weevil or "gru-gru worm," *Rhyncophorus palmarum.*

White grubs are sometimes troublesome, damaging the cane stools. The beetles are referred to as "hardbacks." *Ligyrus* sp. may be quite injurious. As everywhere in continental lands, these Scarabaeid larvae are attacked by certain flies and various Scoliid and Tiphiid wasps.

A large butterfly, *Caligo,* whose caterpillar eats the leaves of sugar cane, awaiting dusk on the trunk of a mango tree in British Guiana.

Of leaf-feeders, are several species of moth caterpillars of the family Noctuidae, and at least ten species of the larvae of the Hesperidae or Skipper butterflies. Such insects, however, do not for long increase beyond the control of their numerous enemies, which in the end slaughter them wholesale. Parasitic flies and wasps are among these foes. A solitary wasp of the family Eumenidae, noticed also in Brazil as the same or a related species, excavates shallow burrows in termite mounds or in the ground proper and stores them with some of these skipper butterfly caterpillars. A fine large butterfly, *Caligo* sp. with a larva that is occasionally common on cane plants has never become numerous enough to be considered a pest.

The cane froghopper has not taken hold in British Guiana. Of aphids a very few, in diminutive clusters, were found on the plant. They appeared a different species from the one in the Pacific and were attended by a ponerine ant. Mealybugs, of which several species occur on cane, are sometimes very abundant. A *Metarrhizium* (?) fungus destroys a great number, while among their insect enemies, are the caterpillar of a tineid moth, a cecidomyid fly maggot and several species of ladybeetles.

Wireworms allied to our injurious forms were not found plentiful.

Coconut palms in British Guiana attacked by the larva of *Brassolis*, an evening butterfly. By day the caterpillars lie concealed in the sack-like retreat and issue at nightfall to feed.

Two insects conspicuously injurious to the coconut palm (*Cocos nucifera*) in this part of the country are the larvae of a rather large butterfly, *Brassolis sophorae,* and that of an immense moth *Castnia daedalus.* The larvae of *Brassolis* construct a silken nest among the leaves, sallying therefrom at nightfall in large numbers. The damage they do to the palm leaves is much greater, though perhaps more periodical than the depredations of the coconut leafroller of Hawaii. They pupate singly on the underside of palm leaves, walls, or any other convenient place. *Brassolis* butterflies are native to South America and their unsightly work is also apparent on the Royal Palms, *Oreodoxa* of Rio de Janeiro, in Para, and elsewhere. The larva of *Castnia daedalus,* makes rather superficial tunnels along the stem, chiefly the upper growing part of the coconut palm, so that in later years the affected plant shows a series of deep furrows, some of which may penetrate well into the interior.

Among the numerous species of palms one sees in South America none seems to suffer more from the depredations of insects than the coconut palm (*Cocos nucifera*), a plant native to the Eastern Hemisphere. The photograph shows the stem of one of these palms disfigured by the borings of a giant moth caterpillar, *Castnia* sp.

The number of beneficial insects as well as the abundance of insecticidal fungi in the front lands of British Guiana is striking. There are many species of ladybeetles (Coccinellidae), insects that in great measure feed upon aphids,

scale insects, mealybugs, white flies (Aleyrodidae) and even upon leafhopper (Delphacidae). One species devours a fungus. While corn is sometimes rather heavily infested with Aphids, the enemies of these insects are quick to transfer their attention from the often comparatively meager fare on grasses and weeds to attack and quickly clean up a corn aphid infestation. I believe that the lady-beetles are the most efficient of these aphid enemies, and at least four species may be found on this plant. Of these the widespread *Cycloneda sanguinea*, a large reddish species is perhaps the most conspicuous and generally abundant; *Ceratomegilla maculata*, another large species is always rarer. A third species of these Coccinellidae, probably a *Hyperaspis* does very good work. The fourth species, quite small, is less plentiful and was found to pupate gregariously on the leaves. Two kinds of Syrphid flies were observed on corn and other aphid-infested plants. The larger of these flies, bluish black with the basal half of the wings fuscous and with a partly brick red larva was always to be had in an aphid colony, the second fly was smaller and was very common in weedy fields. I believe that *Cycloneda sanguinea* and the larger of the two Syrphids were the main eradicators of the corn aphid. A lace-winged fly (Chysopidae) was likewise a conspicuous enemy of the corn louse and of other small insects. Thus corn is rid of aphids, but a tall reed-like grass, related, I believe, to *Arundo*, often shelters quantities of a large pale green plant-louse for longer periods, which no doubt in many cases serves as an alternate host and so helps to tide over these beneficial predators.

Lepidopterous larvae are attacked by many kinds of wasp and fly parasites. Cockroaches have numerous wasp foes. A large solitary wasp of the genus *Monedula* stores its burrows mainly with horse-flies (*Tabanidae*) that pester the stock. Social wasps, whose mecca is the American tropics, destroy innumerable caterpillars. The nests of these wasps range in size from less than a ping-pong ball to an expanse of a large umbrella. As in human beings, these insects vary much in temperament according to species. The smaller ones seem usually mild or timorous—a fortunate state of affairs, as in passing through the bush their nests are very frequently disturbed. A species of *Cerceris* wasp nesting in small secretive colonies stores its four-foot deep burrows with weevils, *Eustylus* and one or more other species, somewhat allied to Fuller's rose beetle, *Pantomerus godmani*, which is frequently troublesome in Hawaii. The sugar cane mealy-bugs and relatives are at times nearly eradicated in places by a green fungus, probably *Metarrhizium*, while *Cordyceps* (?) fungus sprouts fantastically from other insects.

Here and there amid the fields of cane, perches of bamboo branches have been set into the ground for the purpose of encouraging the many insectivorous birds of the region to frequent this environment and there attack the noxious insects. Among such birds are the Kiskadee (*Pitangus sulphuratus*), a large, very useful flycatcher of bold and noisy habits; the "Old Witch" or tick bird (*Crotophagus ani*), that often accompany livestock apparently for the purpose of feeding on the insects aroused by the movements of these animals; the Guiana blackbird (*Quisqualus lugubris*), and the black and white "washer-woman"

(*Fluvicola picta*).

On December 13, I set sail for Rio de Janeiro, Brazil, with Barbados as a transshipping point. Early in the morning of December 17, we dropped anchor at Bridgetown, Barbados. The island is rather low, of tame profile and almost depleted of natural forest. It has the earmarks of an oceanic island, appearing largely of coral formation, with an insect fauna very impoverished in comparison with that of Trinidad to the south. It is an agricultural country and also enjoys a considerable winter tourist trade. The population, mainly negroes, is dense and the whole island has a spick and span appearance.

I am much indebted to Mr. John R. Bovell, superintendent of Agriculture, and to his assistant for information and opportunity of seeing some of the sugar cane cultivation of the island. Sugar cane is cultivated very efficiently. The seed pieces usually of three eyes each are planted in drills. No fire is run through the fields to facilitate cropping. Apart from the modern sugar factories of the island, are small mills where the cane is crushed through the operation of immense windmills, which in some places are a feature of the landscape. Barbados yielded a very effective parasitic wasp when its *Tiphia parallela* was shipped to Mauritius where it is said to control the white grub, *Phytalus smithi*, of that country in a manner comparable to the work of *Scolia manilae* on *Anomala* grubs in Hawaii.

On December 21, I took the Lamport and Holt steamer *Voltaire*, for the south and ten days later arrived at Rio de Janeiro, the beautiful capital of Brazil, a city of more than a million inhabitants. It lies just within the Tropic of Capricorn, and geologically speaking is in a very ancient region. The rocks are largely gneiss, a granite-like material much used in house building and other construction work there. The layer of soil on these rocks is often very scant and the virgin forests, which extend right up to the city, are composed of medium sized trees. Among the landmarks of Rio are the "Sugarloaf" (Pâo de Assucar, 1312 feet) and the "Hunchback" (Corcovado, 2614 feet) rugged precipitous peaks of solid rock, accessible in the first case by an aerial cable car, and in the second by a cogwheel railroad.

Brazil, which has approximately the same area as the United States, is composed of twenty states and the territory of Acre. The states are governed by presidents. The money is decimal, and as in Ecuador and some other countries, subject to annoying fluctuations. Coffee, first in value of Brazilian products, is grown chiefly in the Sâo Paulo region. Other important products are cacao, cotton, tobacco, cattle, sugar and Brazil nuts. Rubber has taken a back seat, at least for the time being.

I am particularly indebted to Dr. Angelo M. da Costa Lima, entomologist in the Department of Agriculture at Rio de Janeiro for his many kindnesses, especially in regard to entomological information and letters of introduction.

The sugar cane industry of Brazil is not in a high state of development. The chief sugar district lies in around latitude 8° south, in the state of Pernambuco; other districts are Campos, in the state of Rio de Janeiro, and Campinas and Piracicaba, near Sâo Paulo. The sugar cane about Pernambuco is obviously superior to grown in the south, where the climate is not so well suited to this

tropical plant. The soil about São Paulo is said to be decomposed basalt; it is of a reddish color and looks like some of our Hawaiian soils; that about Escada, Pernambuco, appears much like fine, partly sandy alluvium, while in Para, near the Equator, it is very sandy except for a rather thin layer of dark top soil. The cane varieties go mainly by their Portuguese names; as Canna Preta, Canna Roxa, Canna Riscada, Canna Branca and Canna Manteiga. In the south, Canna Preta and Roxa suffer considerably from mosaic disease. Cavangire and Cayenna canes were seen in Para. At Campos, I spent several days at the Experiment Station, and at Piracicaba, visited the Agricultural School and the Fazendas (Estates), Costa Pinto, Monte Alegre and Taquaral. At Campinas, considerable time was spent at the Experiment Station plantation and two visits made a little beyond to Villa Americana. In the state of Para, in northern Brazil, a short trip was made from Belem up river about eight miles, to a small area of periodically submerged cane grown for the manufacture of Casaça or rum. Thereabouts also were scattered patches of cacao. Another sugar cane district 100 kilometers by rail from Belem was reached after a most distressing ride of 10 hours, the wheezing locomotive pausing now and then to pick up firewood or to gather breath before negotiating a grade or curve.

Diatraea moth-borers are common also in Brazilian cane fields. At Campos, I was shown two larval parasites of this pest, one a Tachinid fly, the other a Braconid wasp. The *Metamasius* weevil as a cane pest seems generally scarce in this country, at least in the more southern sections. It was said to sometimes attack cane about Pernambuco, and may be present in palms, etc., in the Amazon region. *Cosmopolites sordidus*, its relative in banana stems, was taken in Campinas. Armyworms at times do considerable damage to the leaves, as may the white grub of *Ligyrus* to the roots. Squads of immature grasshoppers of the genus *Tropidacris*, composed of huge insects, are sometimes found in cane fields. Froghoppers or spittle insects of several species are among the sugar cane insects here, and at least one species that feeds largely upon the superficial root system of this plant is reported as quite injurious. I believe, however, that cleaner culture would reduce these insects to a great extent, as they are likely to abound in weedy fields. Mosaic disease was found to the south, a district in which corn was also extensively planted, being frequently alongside of, or even intermixed with the cane.

I worked up from southern to northern Brazil, completing my stay in that country in Belem, the capital of the state of Para, in which I remained nearly two months. Belem is some distance from the Atlantic Ocean and is situated on a branch of the Para River, sometimes considered one of the mouths of the Amazon. The true Amazon is to the north, where it is intersected at its mouth by the Equator. A striking feature, at least to the stranger in Belem, is the abundance and the tameness of the black-headed vultures, here known as "Urubus." These funereally clad birds are early to anticipate the garbage wagon in its morning rounds, when they may be seen scampering in all haste with outspread wings after this sumptuously laden vehicle and perched on it helping themselves to the contents. More agreeable scenes are to be found in a later walk along the mango-shaded streets, or a visit to the small though interesting zoological

A triumvirate of city scavengers. ''Urubus'' in Para, Brazil.

gardens. In this region, as in many others in South America, one cannot fail to notice the "Sauba" ant and its depredations. This insect, also known as the "leaf-cutting" or "parasol ant" belongs to the genus *Atta,* stores its very extensive underground nests with bits of leaves freshly cut from trees or lesser vegetation, including even the sugar cane. Thus plants may be quite stripped of their leaves, which are used by the ants as a medium upon which to cultivate the fungus upon which they feed. Long lines of these insects, each ant bearing its leaf bit aloft, are a common sight crossing roads or following their own path-like trails. The "Saüba" ant then is a serious pest in the American tropics, and while efforts have been made to combat it, the fact that a colony of these insects my constitute, so to speak, an underground village, makes the task a difficult one. The ant is not without its use, however, for the very large, fat-bodied queens, when with the males they issue forth on their nuptial flights in immense numbers, furnish a welcome addition to the scant bill-of-fare of many an Indian family.

A hunt for wireworms at Rezende, at Campinas and at Piracicaba yielded numbers of one or two species allied to the *Monocrepidius* type. In one case, adults of one species could be secured in large numbers on the leaves of corn. In this section of Brazil the larvae have been found damaging the roots of corn, cotton and other crops. No wireworm enemies were seen.

In the city of Belem I found several beneficial insects which might prove useful in the Hawaiian Islands. For the purpose of securing enough of these and of breeding them some sort of laboratory was necessary. Fortunately, a very good place was found as a room in a large house, itself in a big garden, the whole of which was rented by two men engaged in the business of collecting and selling living zoological specimens of almost every description. A large section of the yard, for example, was devoted to artificial fish ponds stocked chiefly with small

mosquito-eating fish, said fish being sold to the Rockefeller Commission which used them in their mosquito campaign. The remainder of the yard was taken up largely with monkeys, deer, birds, etc., supplemented with cages of various kinds of parrots, macaws and parrakeets, so that one might almost take a course of natural history there.

The very city of Belem abounds with mole crickets, of which two species were noticed. They infest the sandy soil of the parks and even work between the cobblestones of the streets. Each species of mole cricket has its wasp enemy, active insects that belong to the genus *Larra*. Sufficient mole crickets were dug up in the yard to use for purposes of parasitization. This digging, mainly in clean sandy soil revealed in addition, the larvae and adults of a predaceous ground beetle with largely subterranean habits. It is a medium-sized black beetle of the genus *Scarites* of the family Carabidae, and may prove a possible enemy of wireworms, white grubs, and the larva of Fuller's rose beetle (*Pantomerus godmani*). A wasp that preys upon middle-sized cockroaches and belonging to the genus *Podium* was secured in some numbers in immature stages. All four species of these insects were successfully transported to Hawaii and liberated in small numbers in what appeared to be favorable situations.

The return trip from Belem, Para, to Honolulu, Hawaii, a journey of over 8000 miles, via New York and San Francisco, was accomplished in 27 days, including a delay of four days in San Francisco, leaving Belem July 1, 1924, and arriving in Honolulu July 28, 1924.

Tolerably large collections of insects were made in South America, including a representative assemblage of sugar cane pests, and many other insects of general interest and of economic importance.

The explorations failed to bring to light any insect parasites of Elaterid wireworms, though wireworms themselves were at times quite abundant. No doubt, further search would in the course of time yield more or less effective parasites of these insects.

Pineapple Insects.

The pineapples cultivated in the environs of Guayaquil, Ecuador, are frequently of large size, their meat is delicate, white and well flavored and containing tolerably large seeds. At San Miguel, about 20 miles from Guayaquil, was a small plantation of pineapples. The plants had a healthy appearance and the fruits often bent the stalks by their weight. The pineapple mealybug was common enough but found in quantity only on young fruit still in blossom. Three such affected fruits were kept in a glass jar for over two weeks in hopes of rearing internal parasites of the mealybug. None such was obtained, however, although some midge-like flies were produced from orange-colored maggots that were feeding underneath but probably upon the mealybugs. The maggots spun whitish cocoons and the pupae were partly extruded from them when the adults emerged. A small, dark-colored Ladybeetle (Coccinellidae) with a mealy larva was another enemy of these coccids. A little moth larva was common on the fruits where it fed apparently upon available debris. The larva of a Lycaenid butterfly of the *Thecla* group was twice found feeding on the pineapple. Its fat, little slug-shaped larva bores into the fruit inducing decay. It is a prolonged

and heavy eater and undoubtedly quite a pest. Two butterflies were reared to maturity. The insect has a wide distribution in tropical America and I recall a caterpillar of this or a related species as being intercepted in quarantine in San Francisco in 1909, on a pineapple hailing from Mexico or Central America.

The pineapple belongs to the Bromeliaceae, a family so immensely developed in the Neotropics that it is no doubt the home of our edible species. "Wild pines," as they are known in British Guiana, are represented as large plants but with small though delicious fruit. The Bromeliaceae occur both as terrestrial and tree-dwelling forms; of the former are several fibre-producing plants, while of the latter we have the so-called "Spanish moss" (*Tillandsia*) and a host of other kinds, some with very handsome inflorescences though a comparative superabundance of leaves. Not a few have rather pleasantly flavored if diminutive fruits.

Forest Conditions

In parts of South America many desirable forest trees, palms and flowering plants were observed. On entering a forest, however, a feeling of helplessness seizes one as he views the assemblage of unknown forms, only here and there doubtfully recognizing some specimen.

In the immediate vicinity of Guayaquil, Ecuador, there are bignoniaceous trees that blossom out before leafing, and such appear from afar as a mass of deep yellow, that rival in beauty the "Golden Shower" (*Cassia fistula*) of Hawaii. In the same environment are certain rather large trees that produce capsules containing downy material with commercial possibilities, while the large, loose, wild cotton bush (*Gossypium*) is spangled with masses of white. More to the interior in the damp forests, palms show great development, from the yard-high dwarf in fruit to slender giants that may exceed 100 feet in height. What was described to me as a "Palma Real" is a tall species that grows at proper elevation on the eastern slopes of the Ecuadorean Andes, where, surpassing in height the trees of the forest, it forms the skyline along the mountains. Strangling fig trees, known in Ecuador as "Matapalos", while by no means so numerous as in the Philippines, often attain an immense size, standing out in otherwise cleared areas of virgin forests as solitary giants too huge and useless to be cut down. On the Andean plateau, the *Eucalyptus* has been planted and has proved valuable both for construction purposes and as firewood, quantities being used for the locomotives of the Guayaquil and Quito Railroad. The so-called pepper tree (*Schinus mollis*) grows naturally in parts of this high land, as does the "Capuli", (*Prunus salicifolius*) a pretty tree with execrable fruit. A departure from ordinary willows is to be found in the "Sauce" (*Salix humboldtiana*), a tall slender tree with much the same habitus as the Lombardy poplar. The "Sauce" is conspicuous in the Andean village of Baños, where examples attain a height of fifty feet or more. Epiphytes (plants which grow on other plants, but do not derive their nourishment from them) often "sit" on trees in immense numbers, particularly in the moister regions; this is especially true of various Bromeliaceae (pineapple family), Araceae (relatives of the "Calla lily"), and of orchids. Scandent cacti are well represented, though perhaps not in the dampest forests. Many of these cactus plants root upon the host itself, not sending other roots

A bromeliaceous plant in eastern Ecuador. This particular species is apparently not found high up in the crown of trees, but fastens itself lower down to the trunk or to stumps. It has petiolate leaves and thus harbors no water in which mosquitoes may breed. In the flower-season it sends forth a beautiful carneous red spike which later discloses yellow flowers.

to the ground. Numbers of the Bromeliaceae bear a handsome inflorescence, pinkish, red, yellow, etc.; their leaf bases may hold considerable water, which forms a good breeding place for mosquitoes, Psychodid flies and other aquatic insects as well as for certain tree toads. The Araceae may be represented by dozens of species even within a very circumscribed area; many are terrestrial and a few that flourish in bogs or meadows are among the most attractive. Handsome orchids are to be found as high up in the Andes as 10,000 feet; terrestrial species are common though often inconspicuous; over a dozen kinds were observed in the neighborhood of Baños. The *Sobralia* are very handsome terrestrial

Sobralia sp. A terrestrial orchid common about Baños, Ecuador. A much handsomer and larger *Sobralia* is found at lower levels.

orchids, with white or purple and white flowers three to five inches in diameter. These are terminal from graceful leafy stems, and the plants were found often in numbers along river banks, or on steep slopes at about 5,000-6,000 feet elevation. A fine white-flowered lily (*Eucharis* sp.) grows naturally in the forests and is much used as an ornamental plant in some tropical cities.

In British Guiana are immense forests composed of many species of trees, with giants such as the great buttressed "Mora" (*Dimorphandra* sp.) a conspicuous element. Along the lower reaches of the rivers and near the coast, the wide-crowned silk cotton tree (*Ceiba pentandra*) rises above its fellows.

A small species of orchid. The plant is fan-shaped, clinging by means of its roots to a branch or leaf; the comparatively large flowers are few and yellow with brown spots. It is common in eastern Ecuador, where it grows and flowers occasionally in such profusion on a tree as to give the latter the appearance of being in blossom. Plant ¾ natural size. Separated flower about $X\frac{4}{3}$

The Sand-box (*Hura crepitans*), a sort of weed tree of poisonous character is another huge, quickly growing species whose trunk is studded with close set spines.

The forests about Rio de Janeiro, while really tropical, are, generally speaking, formed of medium large trees. There are not a few trees here that in the flowering season stand out as gorgeous masses of yellow in a background of dark green, while a small tree belonging to the Melastomaceae is equally beautiful in its garb of magenta blossoms. Conspicuous in second growth areas is the rapidly growing *Cecropia* tree represented by several species; other species of this genus by reason of their pale leaves, stand out in the forest as conspicuously as, though singly or in smaller groups, than the "Kukui" (*Aleurites moluccana*) of the Hawaiian Islands. Growing in moderate abundance upon unhealthy trees between Rio de Janeiro and Campos, was a species of *Cattleya* (?) orchid with handsome purplish flowers; this was one of the few instances noted where orchids were conspicuous for their abundance as well as for their beauty.

A giant *Hura crepitans* tree in the lowlands of British Guiana. It is a quick-growing weed tree of little commercial value.

Royal palms (*Oreodoxa oleracea*) in the botanic gardens at Rio de Janeiro. The palms attain a height of well over 100 feet.

Most of the tropical cities were well planted with shade and ornamental palms and trees. Of the first, the Royal Palm (*Oreodoxa oleracea*) was by far the most striking in Brazil. While not having the whitish stem of the *Oreodoxa regia* in these Islands, they exceed the latter in grace and stature, and aisles of these fine palms show many an individual a hundred or more feet tall. As in the Orient, wild fig trees are favorites in South American cities. The commonest fig tree in Brazil, and it seems to be the same as grown in Guayaquil, was of the strangling type and given me as *Ficus livida*, obviously a close relative of *Ficus retusa*. Other common city trees were *Terminalia catappa, Grevillea robusta, Moquilea tomentosa,* a species of *Artocarpus,* and the "Rain Tree", *Samanea saman.*

Sampling Sugar Cane for Juice Analysis

By J. A. Verret

The commercial value of a sugar cane variety is almost entirely dependent upon its yield of cane per acre and the amount of sugar which the cane contains. When one has fairly large amounts of a variety it is not a hard problem to determine its sugar content. But when one is working with but small amounts of new seedlings or bud selection progenies the problem is much more difficult. Analyzing a few whole stalks at harvest time is not satisfactory in that the results vary within such wide limits from year to year as to be of no great value except as rough approximations.

In the *Memoirs of the Department of Agriculture in India,* Botanical Series, Vol. VIII, in an article entitled "Studies in Indian Sugar Canes," C. A. Barber mentions very briefly a method of sampling which appealed to us as being very sound.

The method is based on the assumption that that part of the sugar cane stalk from which the leaves have matured and died is to all intents and purposes, ripe.

We tried this out this season with what seems to us to be very satisfactory results.

In our bud selection work it is very important to know as soon as possible the sugar content of the various progenies selected. It seems to us as reasonable to assume that bud sports occur affecting the sugar content of a variety as well as the tonnage of cane. The problem was one of sampling.

We have growing at the Makiki Plots, 37 lines of selected H 109, consisting of five different progenies. These were selected several years ago and have been harvested three times.

We decided to make a juice determination on these progenies, using the so-called "dry leaf portion" method mentioned above.

The cane was plant. Seed pieces with all eyes, but one, being gouged out, were used in planting. The eyes were spaced two feet in the line. The lines were 30 feet long, giving 15 stools per line.

In sampling, primary stalks only were used. This can be easily done in plant cane with single eye planting. This gave a maximum of one stalk per stool and 15 per line. Primary stalks were taken in order that all stalks be of the same age.

All stalks were very carefully examined and all which were in any way damaged were discarded. This examination was made both in the field and at the mill. The single stalks were run through the small mill one at a time and the juice from each taken separately. As the crushed stalk emerged from the mill it was carefully examined and whenever appreciable discolorations were noted the juice was discarded. We found this to be the best way to make sure that juice from sound stalks only was being taken.

The stalks were topped immediately below the highest node which held a dead leaf, that is, a leaf which had matured and stopped functioning. With this particular cane this point was generally fifteen leaves from the top, counting the

last rolled leaves as one. The rate of joint formation on the primary stalks seemed to have been very uniform, as the large majority had from 24 to 26 matured joints when sampled.

In the following table we give the results obtained. The analyses represent the average for each line, consisting generally of 15 stalks. A few stalks were discarded on account of borer or other injury.

Row No.	Prog. No.	Brix	Pol.	Pur.	Q.R.	Tons cane per acre	Tons sugar per acre
1 (outside line)	5	16.6	15.18	91.4	8.60	61 9	....
2	3	16.7	15.44	92.5	8.38	68.2	....
3	1	16.6	15.21	91.6	8.56	64.0	....
4	3	16.0	14.71	91.9	8.84	67.2	....
5	1	16.4	15.05	91.8	8.64	74.0	....
6	3	16.3	14.93	91.6	8.73	71.7	....
7	1	16.4	15.08	92.0	8.61	70.3	....
8	2	16.5	15.16	91.7	8.57	57.5	....
9	1	16.2	15.08	93.1	8.55	62.8	....
10	3	16.4	15.24	92.9	8.47	65.0	....
11	1	16.6	15.41	92.8	8.38	53.7	....
12	2	16.8	15.70	93.5	8.19	57.8	....
13	1	16.7	15.51	92.9	8.31	59.2	....
14	3	15.9	14.55	91.5	8.96	59.8	....
15	1	16.5	15.24	92.4	8.50	69.7	....
16	2	15.9	14.42	90.7	9.10	64.9	....
17	1	16.4	15.05	91.8	8.64	68.2	....
18	3	16.0	14.57	91.1	8.97	61.4	....
19	1	16.0	14.73	92.1	8.81	72.6	....
20	2	15.9	14.57	91.6	8.91	62.6	....
21	1	16.1	14.71	91.4	8.87	65.5	....
22	3	16.3	14.95	91.7	8.71	78.0	....
23	1	16.3	15.10	92.6	8.57	58.4	....

Row No.	Prog. No.	Brix	Pol.	Pur.	Q.R.	Tons cane per acre	Tons sugar per acre
24	2	16.5	15.39	93.3	8.37	58.5	....
25	1	16.4	15.27	93.1	8.43	51.6	....
26	3	16.5	15.39	93.3	8.37	66.9	....
27	1	16.5	15.34	93.0	8.41	66.0	....
28	2	16.8	15.56	92.6	8.31	69.8	....
29	1	16.7	15.44	92.5	8.38	65.9	....
30	3	17.1	15.83	92.6	8.17	62.8	....
31	1	17.0	15.88	93.4	7.92	60.1	....
32	2	16.8	15.68	93.3	8.22	58.5	....
33	1	16.8	15.68	93.3	8.22	60.1	....
34	3	16.2	14.85	91.6	8.77	57.4	....
35	1	17.0	16.00	94.1	7.82	62.4	....
36	2	16.5	15.14	91.7	8.60	64.5	....
37	1	16.8	15.54	92.4	8.33	63.3	....
38 (outside line)	4	16.9	15.64	92.5	8.28	79.4	....
Ground							
Aug.	1	16.5	15.30	92.6	8.46	63.8	7.53
"	2	16.5	15.20	92.3	8.52	61.8	7.25
"	3	16.3	15.05	92.1	8.62	65.9	7.64
"	4*	16.9	15.64	92.5	8.28	....	....
"	5*	16.6	15.18	91.4	8.60	....	....

* Progenies 4 and 5 consisted of but one line each and were outside, so are not quite so comparative.

Progenies 4 and 5 having but one outside line each are not directly comparable with the others. But even then in studying the results we find comparatively little fluctuation. The agreement is certainly much closer than if whole stools had been taken for samples.

We next tried individual stalks, taking the primary of each stool for analysis. Although the results vary a little more than the line averages, they are better, we believe, than if the whole stool had been taken.

One such series is given below:

Stool No.	No. of stalks in stool	Weight of Primary	Brix	Juice Test of Primary Pol.	Pur.	Q.R.
1	12	4.7	16.6	15.29	92.2	8.48
2	None	...	....	.....	....	....
3	8	4.0	17.2	15.83	92.0	8.20
4	10	4.1	17.4	16.04	92.2	8.09
5	9	4.1	16.6	15.31	92.3	8.46
6	4	4.0	16.5	14.95	90.6	8.78
7	6	3.8	16.5	15.13	91.7	8.60
8	6	3.8	16.3	15.05	92.3	8.61
9	4	3.9	16.5	15.10	91.5	8.63
10	6	4.3	16.6	15.29	92.1	8.49
11	3	5.1	16.5	15.13	92.7	8.54
12	5	4.5	16.2	14.86	91.7	8.76
13	5	3.9	16.0	14.57	91.0	8.98
14	8	4.2	16.6	15.15	93.4	8.49
15	11	3.1	16.3	14.88	91.3	8.78
Average			16.6	15.18	91.4	8.60

We believe this method offers a practical way to get at the sugar content of our Bud Selection progenies. By working with single eye, (or so-called Cuban seed piece) plant cane, we can go through the area taking the primary of each stool. The rest of the stool remains and can be used for seed later, when the best stools in sugar in the best progenies can be picked.

An interesting test can be conducted along these lines, by taking, for instance, 500 or 1,000 stools. From this, pick the hundred stools with the highest sugar content and the hundred with the lowest. Plant one or two seeds of each alternating, repeating for several crops.

We plan starting work of this nature at Waipio this year.

Growth Measurements

By W. C. Jennings

The subject of growth measurements is being brought up, not as a new idea, but as one which is not receiving the attention it merits. The results derived from the first season of the work at Hawi Mill & Plantation Co., Ltd., have

proven so valuable that we now have visions of seeing most of the plantations, at least the irrigated plantations, eventually coming under some system of agricultural control which will be based on some method of collecting and recording growth measurements.

The purpose of this article is to describe the methods being used at Hawi Mill & Plantation Co., Ltd., where we are already making a practical application of the growth measurement idea to field practices. Before going into the details of the system at Hawi we want to especially emphasize the fact that the conducting of growth measurements does not necessarily mean the employment of trained or high salaried men for the work. Any laborer who can read and write and is in any degree dependable can take care of the time-consuming and laborious part of the work. The checking and recording of the measurements taken by this laborer need take only a small proportion of the time of some plantation office assistant or of some dependable overseer.

Our method of measuring cane stalks is described in detail in the *Record* for October, 1924, by H. K. Stender. Details of investigations and studies as to the reliability of this method are described in the *Record* for July, 1922, and in *The Improvement of Sugar Cane Through Bud Selection* report of 1922 by A. D. Shamel.

In our preliminary experimental work at Hawi, testing this method of measuring cane growth, we secured surprisingly uniform results in tests where measurements were conducted on as few as 30 stalks in a series. One test comparing nine series of 30 measurements each, the results of which were illustrated by graphic curves, gave very uniform results from all nine series, while all the area within the test received uniform treatment.

At Hawi Mill & Plantation Co., Ltd., the general plan is to measure 50 stalks in each field. If the field is planted to more than one variety 50 measurements are taken on each variety.

The locations in the field in which stalks are to be measured always represent, as near as can be determined, average conditions in the field. If a field is very rolling, for instance, and about one quarter of the area is in hollows while the remainder is hills, the measurements are distributed in like proportion, that is, one quarter of the measurements would be taken in the hollows and three quarters on stalks growing on hills. Stalks from stools on watercourses, outside lines, etc., are not measured.

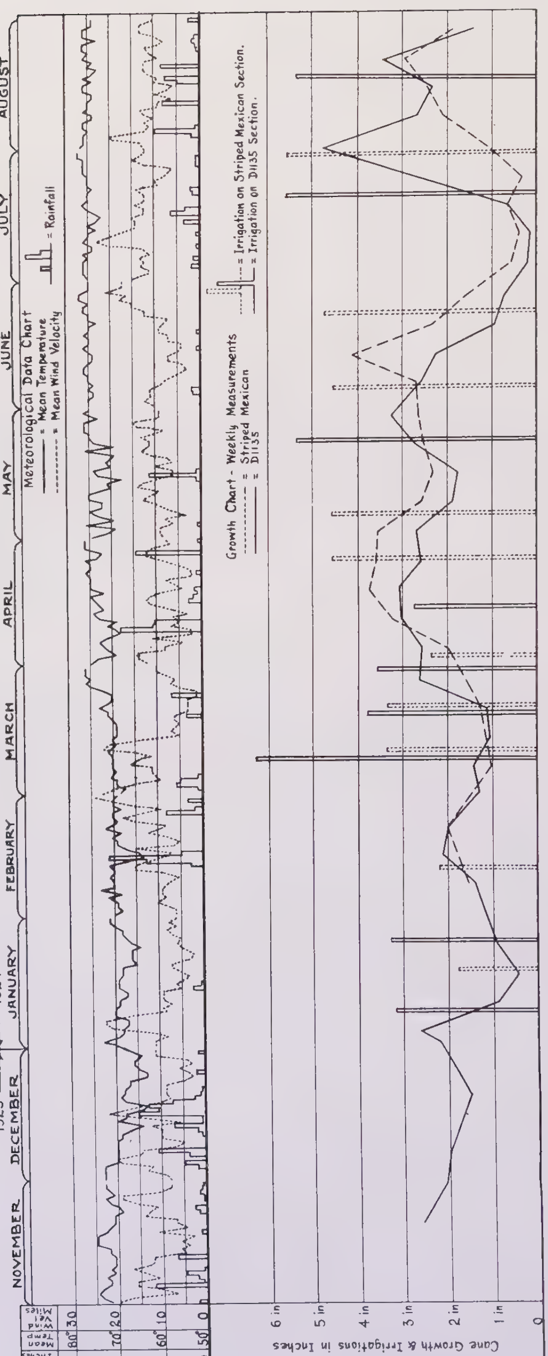
The stalks selected for measurement are marked with Pyroxolin tags giving the stalk number. When animal cultivation is finished in the fields wooden stakes are placed in the middle of the rows near the stalks to be measured. This saves much time in locating the measurements when the cane has closed in. Stakes are also placed around the edges of the field or along the field roads at intervals giving directions for locating the nearest measurements.

Measurements are taken every two weeks on each field. After the stalks have been selected and the first measurement made the work of measuring is turned over to a laborer. Each morning this laborer is supplied with sheets such as the one shown in Table 1 giving the field number, variety and number of the stalks to be measured. These sheets are turned into the office each evening and this

CHART I

GROWTH CHART WITH CLIMATOLOGICAL AND IRRIGATION DATA

Hawi Mill & Plantation Co. Field Hoea 5.



data is entered on sheets such as are shown in Table 2 by whoever is in charge of the work.

The work of the man taking the measurements in the field is checked by the person who works out the sheet shown in Table 2. This checking of the honesty and accuracy of the man who does the measuring works out as follows:

1. The measurements as taken in the field are entered on sheet No. 1 and these sheets are turned into the office every afternoon, leaving no record in the hands of the measurer.

2. The moral effect arising from the fact that whoever is working up the data on sheet No. 2 can at any time check up very easily on any or all the measurements turned in at any time, as the stalks are tagged and numbered and easily located, and the person working up the data can always keep the measurer uncertain as to when and to what particular location he may decide to check up on.

The next most important step in the work at Hawi after the collection and recording of this data is the presentation of it in a form which attracts the interest of the field men. This has been done by means of graphic charts. By showing climatalogical data, time and amount of irrigation by graphic curves on the same chart with the growth curves many interesting and valuable correlations between cane growth and these factors controlling growth have been observed.

Chart I shows a chart worked up for Field Hoea 5 at Hawi Mill & Plantation Company, Ltd.

Chart II shows a chart which is also worked up for each field. On this chart a record of all field operations, such as weeding, fertilization, etc., is kept. Each operation is entered on this chart on the day on which the round was completed.

The growth in each field at Hawi is shown graphically as in Chart I. In addition to this the fields are grouped as follows:

1. Irrigated plant cane.
2. Irrigated ratoon fields.
3. Unirrigated plant.
4. Unirrigated ratoons.

A chart is made out for each of these groups. On these charts are shown the individual curves for each field within the group and also an average curve for each group.

In actual practice this system of charting measurement data is proving to be of great value. If after a periodical measurement any particular field shows either more or less growth than the average for the group to which it belongs, an investigation can immediately be started to see why this is the case. The chart shown in Chart I will show to what extent weather conditions may have affected this unusual growth. If the reason is not apparent in this chart we next look at the chart shown in Chart II and see what has been done to this field in the line of weeding, fertilization, etc., or what treatments may have been omitted on this field, which the other fields in the group have received.

It is possible in this way to keep a very close check on what each field is doing. By knowing what each field is doing it is possible to attempt to bring up fields which are dropping below the average for the group, or again possibly to bring all the fields up to a high standard set by some particular field by studying the conditions that have brought about such a high standard of growth.

CHART II

1st FOLD

(Cut on dotted Lines)

YEARLY PROCEDURE CHART
on a Daily Unit Basis

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
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20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													

2nd FOLD

1st FOLD

The layout at Hawi gives every indication that much of the guess work can be eliminated from cane culture by conducting growth measurements and we can learn the effects of different treatments such as irrigation, fertilization, etc., without waiting one or two years for harvesting results.

Summary

1. Conducting growth measurements, even on every field of a plantation need not be very expensive. The time of a fairly dependable laborer who can read and write, and the part time of an office assistant or a field overseer is sufficient to take care of the work.

2. By installing a system of collecting and recording the measurement data, such as is outlined above in this report, an efficient check on the honesty and accuracy of the man who actually measures the stalks in the field, can be maintained.

3. Showing graphically cane growth together with many of the factors controlling cane growth makes it possible to correlate these factors with cane growth and also gives a complete history of each field that can be easily and clearly seen by the field men.

4. By comparing the growth in different fields with the treatments received it may be possible by changes of treatment to bring up fields in which the rate of growth is below the average or to bring up all the fields in the group or crop to the high standard set by a single field.

5. By conducting growth measurements it is possible to determine the effects of irrigation and fertilization almost immediately. When it is necessary to wait one or two years for harvesting, some condition or treatment other than the one in question may complicate the results.

TABLE 1

Field No. .... Crop. ....

Variety .... Date ....

Stalk Number	Length	Stalk Number	Length	Stalk Number	Length	Stalk Number	Length	Stalk Number	Length

TABLE 2

Field Number 9 Irrigated

Variety D 1135 — Crop 1925, 1st Ratoons

Stalk Number	First Length 7/14	Length 7/28	Growth	Length	Growth	Length	Growth	Length	Growth
1	37.1	39.2	2.1						
2	34.2	37.5	3.3						
3	33.9	36.7	2.8						
4	41.2	42.8	1.6						
5	41.7	43.6	1.9						
6	38.3	41.9	3.6						
7	39.6	42.7	3.1						
8	37.8	40.6	2.8						
9	35.4	38.8	3.4						
10	36.7	39.1	2.4						
11	37.4	39.5	2.1						
12	42.1	45.0	2.9						
13	42.3	45.7	3.4						
14	39.6	41.2	1.6						
15	36.9	39.6	2.7						
16	43.2	45.3	2.1						
17	39.5	42.3	2.8						
18	37.3	50.4	3.1						
19	36.5	38.0	1.5						
20	35.4	38.2	2.8						
21	33.6	36.7	3.1						
22	37.5	41.1	3.6						
23	37.8	41.3	3.5						
24	38.5	40.0	1.5						
25	36.3	39.7	3.4						
26	33.7	35.1	1.4						
27	37.8	40.2	2.4						
28	35.8	37.0	1.2						
39	35.5	37.4	1.9						
30	35.4	36.8	1.4						
31	33.8	36.0	2.2						
32	38.7	41.0	2.3						
33	37.5	41.1	3.6						
34	35.4	39.0	3.6						
35	34.6	35.9	1.3						
36	37.6	39.6	2.0						
37	42.8	44.0	1.2						
38	39.2	42.2	3.0						
39	38.7	41.0	2.3						
40	43.6	45.0	1.4						
41	41.2	43.1	1.9						
42	33.6	36.1	2.5						
43	33.8	35.1	1.3						
44	34.7	36.0	1.3						
45	37.9	40.0	2.1						
46	38.6	41.1	2.5						
47	33.7	35.2	1.5						
48	32.9	34.0	1.1						
49	41.2	43.0	1.8						
50	43.4	45.2	1.8						
Total.....	1885.4	2007.0	121.6						
Average.................		....	2.43						

The Fern Weevil

By C. E. Pemberton

A short investigation of the fern weevil situation in the Kilauea region has just been completed. One day was devoted to a survey of the spread and distribution of the weevil and two days to a study of its parasitism by the Australian parasite *Ischiogonus syagrii* Fullaway.

As was expected, the weevil is slowly spreading. It was found from 400 to 600 feet beyond the original infested area, wherever ferns are available. The present distribution could not be mapped out in a few day's time, but no weevils were found at a distance of approximately one-quarter mile or at even greater distances. We need not greatly concern ourselves with the present exact distribution of the weevil, for in a period of ten or twelve years it will have occupied a large area of forest in the Kilauea country. It is present in the Cooke, Giffard, Young, English, and Carlsmith lots, has spread well into the Olaa Forest Reserve above these lots, is across the Volcano Road into the Shipman forest above the Shipman buildings, and has spread in the Hilo direction as far as the Peter Lee lot. As stated above, it was not found as far as one-quarter mile from the first infested area. A careful search was made in the forest lying between the old Crater Hotel grounds and the infested ground, with negative results. This is a continuous forest and the weevil has penetrated only some 200 or 300 feet into it from the lower boundary across the Volcano Road from the Shipman buildings.

The object of the investigation was to determine the extent to which the weevil is being parasitized and controlled by the introduced parasite.

The weevil is very much under control. The ferns in the new territory into which the weevil has spread are not being killed, in general they are not suffering and a new growth of ferns has appeared and is increasing in the original infested area which was burned in 1920 in an effort to eradicate the pest. Weevils are present on the fronds here and there, usually in twos or threes. Ferns bearing a dozen weevils are uncommon, though occasionally one is seen. There is no massing of weevils on any of the ferns, as was the usual thing in 1920. The attack on the ferns on the original ground and in the new territory into which it has spread is now mild. There is no desolation as in 1920 and it seems fully logical at present to conclude that the ultimate spread of the weevil over the entire Kilauea fern-forest area will be of so mild a nature that neither ferns nor native forest growth, dependent on them for ground cover, will suffer.

This reduction in beetle abundance and damage would appear to be solely owing to the activities of the imported parasite, *Ischiogonus*. It is abundant and effective both in the old and new areas of weevil infestation. It is parasitizing the larvae of the beetle at the very limits of its spread. As near as could be determined, the parasitism now amounts to 60.7 per cent. The exact degree of control could only be determined after many weeks of study and the above figure is made only from counts made here and there over the entire infested region. It is based on an examination of 403 channels made by the beetle-larvae

in the fern stems. Growing larvae were not considered, as they might yet be parasitized before reaching maturity. Unparasitized individuals were those larvae which had pupated or matured to beetles and left in the stem the typical emergence hole of the adult. Parasitized individuals were those wherein the borer channels showed the clusters of parasite cocoons, either empty or still occupied, there being 1 cluster per parasitized individual. In this manner I found, in the older fern stems, 158 beetle emergence holes or beetle pupae and 245 clusters of parasite cocoons. Sometimes the cluster in the channel comprised only 2 or 3 cocoons and occasionally only one. The adult parasite wasps were seen hovering about in the ferns wherever the weevil occurred. The parasitism was particularly high among the young ferns springing up in the burned off area. This is because the stems of the young ferns are small and the contained beetle grubs are very easily reached by the sting of the parasitic wasp.

I believe the recent ash eruption of the Kilauea Volcano has temporarily interfered, to some extent, with the efficiency of the parasite. The entire forest, for several miles around, was coated with this ash and formed a mud-like layer over most of the fern stems. This must interfere a good deal and prevent the female wasp, which is small and delicate, from properly ovipositing on many of the weevil larvae lying within the coated fern stems. I am indebted to Mr. W. M. Giffard for advance information respecting this. However, if there has been such a check, it was only temporary, for the parasite is now actively operating. This mud still remains on the stems. Over the entire area covered by this eruption and particularly where the ferns are shaded and tender, much of the growth is broken and dead from the weight of the accumulated mud-like ash. Tender fronds have broken in halves, the outer half hanging dead. The tips are likewise hanging dead on many of the ferns and often whole fronds have fallen over and withered from the same cause. When entering the weevil-infested area one would first ascribe this damage to the insect, but examination soon shows it to be otherwise, particularly when the uninfested area is visited.

Welding As a Reclaiming and Manufacturing Factor*

By Arthur G. Cooper

There are several commercial processes of welding worthy of mention, but, as only three of these are being used in Hawaii, the purpose of this paper is to partly cover the field of application of these three processes. They are, according to their respective fields of application, Electric Arc, Oxy-Acetylene, and Thermit.

Electric Arc: There are two kinds of electric arc welds; the metallic arc process and the carbon arc process.

On account of its simplicity and general superiority, the metallic arc is more generally used. The physical characteristics are, however, quite similar. The

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* Presented at Third Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 27, 1924.

physical characteristics of both are determined chiefly by the perfection of fusion between the pieces of metal to be united.

The metallic process is more readily examined to determine its degree of fusion. This is usually accomplished by breaking the arc while welding is in progress and observing the depth of the crater. The operator may also observe the depth of penetration while welding is being done and judge as to quality of the weld. The only exception to this, however, is when a current of too great a density for the welding electrode or the thickness of the metal being welded, is used. The importance of this cannot be too strongly emphasized when breaking in a student welder, as the strength of the weld depends largely on the current density for various size electrodes. The following table represents the approximate values of arc current and electrode diameter for various horizontal plate thicknesses used by the leading manufacturers and repair shops:

Thickness of metal	Amperes Arc current	Electrode diameter
1/8 inch	50—75	1/32 inch
1/4 "	85—125	1/16 "
3/8 "	125—150	3/32 "
1/2 "	125—175	1/8 "
5/8 "	135—185	5/32 "
3/4 "	150—200	3/16 "
7/8 "	175—225	3/16 "
1 "	175—250	3/16 "

The overlapping and welding of two plates of the thicknesses given in the above table, however, will necessitate increasing the arc current and the electrode diameter due to the increased thermal capacity of the two sections. In lap welding two such sections, the current should be approximately 100 per cent higher. After the required current has been obtained, the electrode diameter should be increased. The required size can be found by referring to the above table for electrodes corresponding to various currents.

The electrode material is also an important factor. To prevent unfused areas from occurring in the weld, it is necessary that the fusing temperature of the electrode should exceed that of the metal to be welded. Pure iron has a very high melting point, but, due to its high affinity for oxygen in its vaporized form, excessive oxidation occurs, resulting in an inferior weld. The use of an electrode with a lower melting point than that of the metal to be welded results also in an overlap resulting in unfused pockets underneath the deposited metal.

There are numerous ways of determining the character of a weld. The factors which determine the physical characteristics of a metallic arc weld, however, are fusion, slag content, porosity and crystal structure.

A visual examination of a weld may be made to determine the surface finish indicating the operator's regard for good workmanship, length of unbroken deposits, indicating ease of operation and ability to control the arc; uniformity of deposit indicating faithfulness of operator in depositing metal in its required place; proper fusion of metal at bottom of weld as shown from bottom of weld; amount of surface porosity and slag indicating either of three things, machine of inferior design, unsuitable electrode or improper preparation of metal.

The applications for electric welding are many and varied, but, principally to repairing and manufacturing ferrous metals. It is believed that anything made of steel can be repaired by the electric process, considering, of course, the ultimate strength any electric weld would have when made under favorable conditions as compared with the strength of the parent metal. It should also be remembered that electric metal that has been deposited through an electric arc is no longer a piece of rolled steel but cast. The natural thing to do, is to make our finished welds possess as near forging characteristics as possible, especially where the amount of deposit is limited for lack of space.

The approximate speed of electric arc welding is given in the following table:

Plate thickness	Speed of welding in feet per hour
1/8 inch	30
3/16 "	25
1/4 "	20
1/2 "	4

In general, an estimate can be made allowing 8 to 10 cubic inches of deposited metal per hour using a current 175 amperes and an electrode of 5/32 inch.

The cost of electric arc welding will average about 3 to 1 in favor of the arc over gas, except on sheet steel of 1/8 inch or less.

Gas Welding: The French must be given credit for producing the first commercially successful oxy-acetylene blow pipe or torch, about 1901. The torch is in reality the heart of the gas welding system, as it must function to supply the oxygen and acetylene at the proper rate to produce a flame for satisfactory welding. The combination of oxygen and hydrogen is also used for gas welding and cutting.

When welding with the gas torch the flame is directed against the material to be welded. The filler material in the form of a rod is also held in the flame, which causes it to be melted and unite with the molten portions of the material. The proper adjustment of the gases must be made so that the flame will be neutral and not oxidizing.

The oxy-acetylene flame is not intrinsically as hot and the heat is not nearly so concentrated as that of the electric arc. For this reason, the chief welding field for gas at present is that of the sheet metal of less than one-eighth inch in thickness and for non-ferrous metals. If the joint must be very smooth, the gas process will undoubtedly give superior results in the long run. There is also less tendency to burn the metal when working with thin material, this being due to the fact that the gas welding flame produces a lower temperature. Since the gas flame is not as hot and concentrated as the electric arc, the time required to perform a weld in thick material is in the ratio of 2 or 3 to 1. This condition together with spreading of flame, results in much trouble due to expansion and contraction of mild steel plates. The actual difference in cost of gas and arc welding had been found by some investigators to be as high as 3.1 in favor of the arc, taking all charges into account.

Based upon statistics obtained from various sources, it has been found that the cost of welding 1/8 inch plates is about the same for gas and the arc. Plates

1/4 inch thick can be welded by arc for about half the cost of gas welding. For plates 1/2 inch thick, the arc cost will be from 25 per cent to 15 per cent that of gas. These figures are based upon total costs of doing the work.

The oxy-acetylene process is subject to the same criticism as the carbon electrode process, namely, that it is possible for a careless or inexperienced welder to melt the filling material too rapidly, thereby causing it to flow over unfused surfaces of the work, which produces a weak weld. In the hands of a skilled operator, however, thoroughly satisfactory welds can be executed.

In the field of cutting, the gas flame, although more expensive, is preeminently the better for cutting mild steel plates, angles and shapes. For this work, a special tip is used, which reduces the acetylene to a minimum sufficient to support the flame, whereas the oxygen is supplied in greater quantities. The action produced is that of oxidization or burning, which takes place very rapidly, with the removal of a minimum amount of material. The action is the same as that of the familiar physics experiment wherein a piece of watch spring is heated to a red color in a Bunson flame, after which it is dropped in a bottle of pure oxygen, whereupon the spring is rapidly consumed, accompanied by a rather spectacular pyrotechnic display. Cast iron, however, contains such a large percentage of carbon, both combined with iron and in the free state, that the burning process cannot be used. The metal must be actually melted and, therefore, the electric arc is faster than the gas, owing to the difference of the intrinsic heat values.

Thermit Welding: The Thermit process of welding differs principally in the rate of application and the removing to a great extent of the personal element. According to different engineers, this comprises about 90 per cent of the efficiency of the other two processes. Any progress made in the removal of these elements naturally will result in welds that more nearly approach 100 per cent efficiency. The personal element is, to a large extent, eliminated from the Thermit process, inasmuch as the various involved steps in making a weld are in a measure changed to mechanical operations that are under control of the operator.

The making of a Thermit weld will not be gone into in detail here.

The field of application for Thermit welds differs slightly from the other two processes in that it is particularly applicable to pipe work, rail welding and more especially large sections, such as roller shafts, pinions, locomotive frames, marine repairs, crank shaft repairs, etc. In fact, the field of application very seldom overlaps.

The tensile strength of a Thermit weld exceeds either the electric or gas due principally to expansion and contraction taking place in the whole welded mass simultaneously and the exclusion of oxidized portions. It is a physical impossibility to eliminate shrinkage strains by applying only small portions of molten metal and allowing this to cool in the same manner. We are also unable to prevent oxidation completely. This obviously eliminates gas or electricity where it is possible to use Thermit, especially when a weld should be as near perfect as is possible to obtain.

Report of the Committee on Irrigation*

By Frank W. Broadbent

In presenting a report on the subject of irrigation, the objects have been, first, to follow up points mentioned in last year's report but upon which data was not available at that time; second, to make notes of such items of progress on which it has been possible to secure information, and finally to suggest a few topics upon which we might have a general discussion.

Hawi Overhead System

It was sugested in last year's report that there might be trouble after a while with the sprinklers clogging, due to the accumulation of rust, dirt, etc., in the pipes. Manager Hind writes, however, that in the installations that have been in operation for seventeen months no trouble with clogging has occurred.

At Hawi they have found that 1½ acre inches per week of overhead irrigation is sufficient for maximum growth in young cane. With older cane about 3½ inches every two weeks is necessary. A study is being made as to just what age the change should occur. Another study that is being made is on soil moisture and growth measurements, resulting from overhead irrigation as against the same resulting from irrigation applied by the usual contour system. Mr. W. C. Jennings is carrying on these investigations.

No major improvements have been added to the Hawi system, but they have come to the conclusion that with the size pipes they are using on the laterals the length should be no greater than 450 feet. (These lateral pipes vary in size from 2 inches down to ¾ inch at the far end.)

Orchard System of Irrigation

Kilauea Plantation reports that they have nothing new to offer on the Orchard system of irrigation that has not been presented in previous reports.

At Koloa Sugar Co. an experiment using the Orchard system was harvested this year. Another will come off in the 1925 crop. Of the 1924 test Manager Moir does not feel that the results are such as to permit of any decisive comment. The following interesting notes are made, however: (1) That the Orchard system yielded about 1½ tons cane per acre more than the contour system. (2) That this higher yield is offset by the fact that the Orchard system received eight full irrigations for the crop as against three for the contour system. (Note: This test was laid out in a mauka semi-irrigated field.) (3) That the cost of laying out an area is cheaper per acre than it is for the contour system. (4) That the distribution of water by the Orchard system is not effected as evenly as it is possible with the old system.

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* Presented at Third Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 27, 1924.

The test for the crop of 1925 at Koloa Sugar Company is laid out in one of the steadily irrigated makai fields of H 109 cane. Measurements have been kept of the water used by each system, and to date it is found that the Orchard uses from 20 to 25 per cent more water per irrigation per acre than the contour system.

From Ewa Plantation Company it is reported that the test of the "no watercourse" or Orchard system is being continued in ratoons with the object of obtaining more data on yields before conclusions are drawn. The system here is noted as a labor saver and as not requiring more water than the regular Ewa system.

A test for the 1924 crop, comparing the Orchard system, Peru system, and 32-foot and 40-foot watercourse of the regular contour system, has been running at the Oahu Sugar Company, Ltd. Interesting figures on the water consumption of each system were presented in last year's report.

Baldwin Flume System

The Baldwin flume system is being tried out at the Maui Agricultural Company, Ltd., by Mr. H. W. Baldwin, the originator. A layout of 150 acres is to be harvested in the 1925 crop.

Ditches

Pioneer Mill Company, Ltd., has in the last year lined 2½ miles of the Honokahau Tunnel with concrete. This lining is put in with forms, is 4 inches thick and has no reinforcing. The inside dimensions are, depth 4 feet 6 inches, width at top 6 feet, and width at bottom 4 feet 3 inches. It is designed to carry 50 million gallons per 24 hours.

The Hawaiian Commercial & Sugar Company have re-dug and concrete-lined approximately 2 miles of their Camp 7 ditch. This is a 21-million gallon ditch. The top width is 7 feet 11 inches, bottom 2 feet 5 inches, and depth 3 feet; grade 5 feet per thousand.

The method of pouring concrete lining in this work is quite interesting. The main points are described in W. P. Alexander's bulletin *The Irrigation of Sugar Cane in Hawaii.* To quote: "A 3-inch concrete is placed without forms on the ditch banks, which have a 1 to 1 slope, and likewise on the ditch bottom; the concrete is followed up immediately with a plaster finish * * * The plastering being placed immediately upon the unset concrete bonds with it perfectly * * * We find it necessary to place expansion joints every 15 feet in this 3-inch lining. If farther apart, expansion and contraction, due to changes in temperature, have caused cracking. We use no reinforcing in this concrete. Probably the expansion joints could be placed further apart if reinforcement were used."

The concrete used is mixed quite stiff and consists by volume of 1 cement, 2½ sand and 4 rock. The plaster is the same less the rock. The mixing is done in a "Rex" mixer mounted on a movable platform which is shoved along as the work proceeds. The following series of photographs show the details of operation more concisely than can be described. Sixteen men form the mixer

crew and one 15-foot frame per man per day, or a total of 240 feet, is the regular rate of work. The finished job presents a very neat ditch and evidence of lasting qualities is to be seen where such ditches have been in use for several years.

The Wailuku Sugar Company's pre-cast concrete slab-lined ditches are standing up well. Note the sweet potato vines and pigeon peas growing along each side, thus saving hoeing and keeping weed seeds out of the irrigation water.

CONCRETE DITCH LINING AT HAWAIIAN COMMERCIAL & SUGAR CO.

Above: General view of the outfit used. The 2″ x 4″ stringers along each edge of the ditch are the only forms used in this work.

Below: Three men trim sides ahead of mixer, put edge forms in place and lay tar paper for expansion joints. Five men supply materials from cars to mixer skip. Two men operate mixer. Two men shovel concrete up on ditch sides. Two men tamp concrete. One man smooths off plaster. An expansion joint is placed every 15 feet

Concrete Ditch Lining at Hawaiian Commercial & Sugar Co.

Above: The mixer is run along on planks, as shown in the foreground. A one-cylinder "Novo" engine furnishes power. The hose at the right leads from the engine-driven pump to an old ditch from which water is obtained.

Below: Applying the plaster finish immediately after the concrete has been placed. One man stays behind and does the smoothing off while the concrete work proceeds.

Lining by means of cement plaster on chicken wire reinforcement is no longer practiced on Maui because of unfavorable results gained from previous work. Such lining gives way and cracks easily because of its thinness and unevenness of application to the ditch sides.

Concrete Ditch Lining at Hawaiian Commercial & Sugar Co.

Above: After the previous day's work has set over night, one man applies a coat of waterproofing cement wash with a whitewash brush.

Below: A section of the finished ditch.

Water Measurements

Increased interest in water measurements is manifested by the growing number of measuring devices used in the Islands. The Great Western Meter Company reports the sale of 232 Lyman meters here, the East Kauai Water Company, Ewa Plantation Company, Hawaiian Homes Commission and the Waimanalo Sugar Company, being supplied with the greatest number of meters in the order named.

Wailuku Sugar Company Pre-Cast Concrete Slab-Lined Ditch

These two photographs show a section of cast concrete slab-lined ditch that has been in place for four years. Other sections that have been in place for an additional two years look as well.

At Hawi Mill & Plantation Company, Ltd., several of these meters are in use in conjunction with the sprinkler system and have been found accurate and handy.

Mr. John M. Watt, who is in charge of irrigation investigations at Ewa Plantation Company, reports as follows:

This meter (Great Western) is not an expensive machine in comparison to other measuring devices in operation for this work. The original outlay is moderate, and upkeep is practically nothing. It is fool proof and so requires little attention aside from

daily readings and also seeing now and then that it does not become fouled * * * We have found that the cost of installation of meter structures is very reasonable * * * One carpenter and a helper can make from two to three of these structures in a day. Two men can install from one to three structures a day in the field, depending on the nature of the ground they are working in.

Mr. Joel B. Cox, of the McBryde Sugar Company, writes:

We are using Stevens Water Stage Recorders extensively in our water measurement work here. For ditch measurements we have adopted rating stations equipped with the Type E-Recorder. As no weir or submerged orifice is used, the total cost of the installation is the least of any available method, and in many cases the additional labor in working up the records is offset by the value of having a complete graphical record of the flow, which cannot be obtained with such a device as the Great Western Meter. We have found the Type E-Recorder very satisfactory in operation. The cost is a little over $60 per instrument.

Another type of meter that is being tested at Waipio is the "Reliance." This make differs from the usual run of meters in that all of the water measured passes through the instrument.

Mr. Cox has done some work in correlating yields of different varieties with amounts of water used on the same. Plotted curves show that H 109 yields highest, D 1135 next and Yellow Caledonia third from a given quantity of water under McBryde crop conditions.

At Waimanalo Sugar Company, a very interesting series of tests are being carried out correlating water measurements and cane growth. This work is not an end in itself, as it was desired to obtain information as to the "maximum amount of irrigation water which the plantation could use and produce an adequate return in the production of additional sugar."

A report of the earlier stages of this work is to be seen in the *Record* for April, 1924. Since this report additional work has been done, and it is hoped that we might hear of this at this time from Mr. Stewart.

Pumping Plants

Small pumping plants are in use on several plantations, either for supply or drainage purposes. Fairbanks, Morse Semi-Diesel engines are found to be suitable power units for these plants. There are some eighty of these engines in operation in the Islands and Mr. F. E. Richardson, local agent, offers the following information on certain installations:

The Fairbanks, Morse Engines are two-cycle solid injection of the Semi-Diesel Type and are guaranteed to develop their full rating on 46 pounds of oil per horse power hour at full load.

Kekaha Sugar Company, Ltd., has two 75 h.p. Fairbanks, Morse Semi-Diesel Engines, each driving an 18-inch Type 800 Splitcase Fairbanks, Morse Pump delivering 10 million gallons of water per 24 hours against a total head of 26 feet. Each engine is operating on 5 gallons 24 gravity fuel oil per hour, total 120 gallons per 24 hours at 5 cents per gallon or a total cost of fuel of $6 per 24 hours. Lubricating oil at $1.50 per day makes a total of $7.50 for 10 million gallons, making the cost of water pumped about 75 cents per million gallons excluding labor.

These two plants when operated together pump 20 million gallons with one day and one night engineers.

We recently installed at Kekaha a 150 h.p. Fairbanks, Morse operating a 12-inch centrifugal pump having a capacity of 6 million against a total head of 98 feet.

This engine consumes 10 gallons fuel oil per hour and $3 worth of lubricating oil per 24 hours, making the cost of operating for 24 hours $15 per day or at the rate of $2.50 per million gallons.

Kekaha Sugar Company has two 75 h.p. Fairbanks, Morse Type "Y" engines in their Mana section, driving two 18" Fairbanks, Morse Splitcase Figure 800 Centrifugal pumps. Each pump delivers 10 million gallons of water, making 20 million against a head of 26 feet.

Waianae Company has eight Fairbanks, Morse engines in operation ranging from 75 to 10 h.p.

In regard to the engines at Waianae Company, Manager Brecht states:

A 4-inch pump run by a 15 h.p. Fairbanks, Morse Semi-Diesel engine, pumps about half a million gallons of water 60 feet high.

Consumption of fuel oil is, roughly speaking, 2/3 of a gallon per hour for a 15 h.p. engine, the price of fuel is 5 cents per gallon.

This amounts to a cost of $1.60 per million gallons.

Drainage

A 58-acre field at Ewa Plantation Company is laid out with some 12,000 feet of tiled drainage. That interesting results are being obtained here is to be seen in the following paragraphs from Mr. W. P. Alexander:

The tile drainage system at Ewa has been in operation for fifteen months. During this time a complete control has been had of the amount of water applied to the cane, and the amount of and analysis of the drainage water discharged by the tile. Until the crop has been brought to maturity, it is possible to answer any question in a very preliminary manner only.

(a) Harvesting data will show whether the drainage of sugar cane land by means of tile is profitable. The "acid test" will be a comparison of the sugar yield obtained with the tile with former yields.

(b) There is good evidence that salt which has accumulated in the soil over a period of many years, is being reduced. Fifteen months ago the drainage water contained 80 grains salt per gallon and at the present writing it analyzes 50 to 55 grains. At the time of heavy rains the salt content of the leachings has gone as high as 100 grains. Calculations of the salt content with the amount of water leaving the field in the tile shows that to June 30, 1924, 71 tons of salt had been removed from 58.3 acres.

(c) With cooperation of the Experiment Station, the leachings have been analyzed for the three main plant foods, which are applied as fertilizers. The purpose of the investigation was to determine how permanently fixed in the soil of this type are nitrogen, phosphoric acid and potash. Here was an opportunity to accomplish on a field scale with sugar cane what has previously only been tried out in a laboratory with lysimeters. The results have a very practical application in regard to fertilizer practices.

Phosphoric acid was sometimes found in "traces," but usually not at all.

Nitrogen in the nitrate form was present in minute quantities. The amount of nitrate nitrogen leached out through the tile in 12 months came to 10.87 pounds per acre or less than 5 per cent of the total nitrogen applied as fertilizer.

Potash seemed the least fixed in the soil. The drainage water always contained some K_2O in very small amounts. When calculated on an acre basis, however, the leachings of potash were not large, representing about 10 per cent of the total potash applied to the field as a fertilizer.

Discussion Topics

Have we any further data as to what the optimum length of and space between furrows should be?

What angles should the furrow make with the watercourse, right, acute, or obtuse?

When should dirt be pulled out of the line, after closing first water or second water?

Is the practice of cutting lines ("moku" system) very general? What are the reasons for using this system? When it is practiced, at what stage of the cane's growth should the cut be made in the line?

Any further data on optimum number of lines between level ditches?

Should lines be laid out level or with some grade? If the latter, how much?

To what extent is every-other-line irrigation carried on when short of water? Where practiced, is it confined only to hilled-up ratoons, or to all canes? Where practiced, what is the type of soil, i.e., is it loose and porous or finely divided and easily packed?

Do you save water by irrigating every other row or not (is it not possible that more water is put into the row with this method)?

If, say with 5-foot lines, there are arguments in favor of spacing seed, would it not be just as effective to plant close in the lines and to space the lines further apart? With a less number of lines, there would be a saving of water, etc.

Is it preferable to put in watercourses with the bottom level with the bottom of the line, or with the watercourse bottom above that of the line and with the sides built up?

Where should the trash pani be placed in the watercourse with respect to the furrow?

Where should the cut in the watercourse be made for first water? Where for second and subsequent waters?

The usual method of irrigation, where the single line method is used, is down the watercourse one round and up in the next round. At Hawaiian Commercial & Sugar Company, the watercourse is worked in both directions in each round. Is this practice carried on elsewhere?

What grade should level ditches have?

Is it more economical to make long levels and few straight ditches or the reverse?

Is it better to use reservoir water as the canes need it or to hold it back for expected dry months with seepage losses?

What varieties really are the most drought resistant? Does H 109 take more water or does it curl its leaves merely as a protective measure?

In a shortage of water would you use what is available on the 1925 or the 1926 crop?

In the dry season how many million gallons per day can be counted on by units of acres on the various plantations?

Are the benefits of (1) poepoe, and (2) hilling-up direct in that they actually boost the cane along or are they indirect in that they help to make irrigation, etc., more efficient?

Considering unsoaked seed, what should be the interval of time between first and second water? Second and third? Third and fourth? Fourth and fifth?

Does soaking seed save an irrigation and if so what is the effect on the length of time between irrigations? What is the optimum length of time to soak seed?

After which irrigation should contracts be started?

Is it good practice to irrigate more than one watercourse per man, starting with the second water?

If irrigating ratoons or big cane by men other than the cultivation contractors, what is the best basis of pay in order to get a good job done by the acre, number of lines or day work?

What is the primary basis of the distribution of the water supply over a plantation? This first distribution of the total water is a vital matter on an irrigated plantation, and whatever the basis is, how certain are we of the correctness of our present practices? Should not more effort be directed toward obtaining results which will enable this first distribution to be based on definite facts rather than on opinion and guess work?

Plantation Electrical Equipment*

By E. Butler Smith

This subject, as outlined by the Chairman of the Engineering Section of this Association, is rather broad and could be made to cover practically all phases of electrical work found on a plantation. The use of electricity is becoming so general on Hawaiian sugar plantations that it does not seem necessary to make any plea for its use. The only job that has been left exclusively to the steam engine is the crusher and mill drive. Successful motor drives on the mills and crushers have been installed in other countries and may be eventually tried here. I shall, therefore, include the choice of a mill drive in this paper.

Electrical Equipment for Cane Sugar Factories

The first item that must be considered in any new electrical installation is the type of motor to be used. Assuming that we are not limited by an existing generating plant, the first choice is alternating current, three phase, 60 cycles, 440 volts. Direct current motors would have certain advantages in many cases but the expense of maintenance of D. C. machines and the difficulties in transmission of direct current power in large quantities far outweigh these advantages. The three-phase circuit is the simplest to wire and has the greatest possibilities as far as transmission is concerned. Sixty cycles is the most popular frequency for general use in the United States, which means that 60 cycles apparatus is most readily obtained. We select 440 volts as the highest standard voltage with which we can use standard low voltage wire and knife switches and fuses. The question of switches and fuses will be considered later on.

There are two types of motors to select from: induction motors and synchronous motors. The induction motors are either squirrel cage or wound

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rotor. The squirrel cage motor is the cheapest and simplest, is least affected by dust and dirt and requires the least attention but has the disadvantage of poor starting characteristics and inconstant speed. This is the type that should be used wherever possible. The wound rotor motor costs more, requires a more complicated control, having slip rings and brushes, is troubled by dust and dirt and requires more attention. It has the best starting characteristics and can be used for variable speed drives. Both of the above types of motors have the disadvantage of having a power factor of less than unity which falls off rapidly when the motor is underloaded.

The synchronous motor requires the most complicated control, more maintenance and care in operation but has the advantage that the power factor is controllable and may be so designed and operated as to a leading instead of a lagging current. A synchronous motor operating with induction motors can be made to take a leading current and thus correct for lagging current taken by the induction motors. This will allow the generating station to operate under more favorable power factor conditions than would otherwise be possible. A synchronous motor to be of much use for power factor correction should have a constant load. If the load varies field adjustment becomes necessary and adds to the expense of operation by requiring constant attention. There are two places in a mill where a synchronous motor may be installed to advantage: on the circulating pump and on the vacuum pump.

Personally, I would not advise the installation of a synchronous motor unless it can be shown that a considerable saving will result in the generating plant or transmission system. Where power is purchased from central station companies a considerable reduction in rates can often be obtained by the installation of synchronous motors, but where the generating station is located in the mill, as is usually the case in these Islands, I do not think that a synchronous motor is justified.

This leaves for general application only the two types of induction motor. Since the squirrel cage motor is the cheapest, simplest and most free from trouble it should be used wherever possible. Wherever constant speed and low starting torque are required the squirrel cage motor will prove most satisfactory up to one hundred horse power. For sizes in excess of this, I believe that wound rotor motors should be used because of the lower starting current. For centrifugal pump drives I think the limit should be set at fifty horse power.

For driving a Searby shredder the wound rotor motor is best suited. Here we require a large starting torque. The load fluctuates considerably depending of course on the evenness of the feed. Since the shredder is provided with a flywheel and has considerable flywheel effect in itself the motor chosen should be of such size as to handle the average load with a fair margin of safety. The puniary switch for this motor should be an oil switch with overload relays having an inverse trine setting. The secondary control should be of the enclosed drum type as this type is more easily protected from dirt and dust.

For a motor drive for the crusher and rolls the wound rotor motor is selected because we require high starting torque and variable speed. The full required speed variation can be obtained by secondary resistance control. There are,

however, certain disadvantages found in this method. At reduced speeds the motor efficiency drops off rapidly due to the large amount of resistance used in the secondary. The resistance grids or water rheostats must be very large in order to dissipate the large amount of heat generated at reduced speeds. Furthermore, with a high resistance in the secondary, the motor speed is unstable. This method has the advantage that it is the simplest and easiest to install and operate.

If the resistance speed control method is not satisfactory the variable frequency method can be used. In this method a separate generator and prime mover is used to supply power for the mill drive. The governor on the prime mover is designed for sufficient speed variation to take care of the speed variation required in the operation of the mill. The desired speed variation between mills and starting is taken care of by resistance control. By this method the resistors can be made much smaller and there is less loss of efficiency due to heat generated in the resistors. The prime mover governor would be motor regulated and the control switch placed on the mill operating platform. As soon as the relative speed between mills is adjusted the speed of the whole train can be raised or lowered by operating the governor motor switch.

For mill motor secondary control the liquid rheostat will prove most satisfactory. In the first place the control can be made as close as desired as there may be any number of steps. Furthermore, there are no contacts to become loose, heat up, and otherwise give trouble, and there are no hot grids to get covered with dust and catch fire.

For puniary control of the mill drive motors, oil switches should be provided with a slow time setting, or better yet, a thermal relay. Oil switch and rheostat control should be so interlocked that it is impossible to close the oil switch until the rheostat control is brought to the starting position.

For the cane carrier drive a wound rotor motor with extra large resistors for variable speed service will be required. A drum type controller should be used which should contain the puniary switch as well as the secondary rheostat switches. With this type of control the operator has only one lever to handle and the starting and stopping of the motor is made easy and convenient.

The remainder of the drives in the sugar factory can ordinarily be handled very nicely with squirrel cage motors. Motors of 5 h.p. or smaller can be thrown straight across the line and require only a safety starting switch for their control. Motors larger than 5 h.p. should be provided with starting boxes of the auto-transformer type, and should be protected by relays.

One of the most important things to be considered in the electrical equipment of a sugar factory is the electrical distribution system and the protective devices.

All wiring should be run in conduit, and the conduit should be laid out so that it does not come too close to steam pipes. Four hundred and forty volts were chosen for the motors so that standard 600-volt rubber-insulated wire and switches could be used. Unless the conduit can be encased in concrete for the full length of the run, metal conduit should be used. Conduit fittings, rather than pipe fittings, should be used throughout. With the wires enclosed in conduit, there is no danger of workmen receiving accidental shocks through con-

tact with a wire. The wire is not pulled down and broken or otherwise disturbed by scaffolding and tackles during the overhauling period. The wiring is protected from oil and dirt and the appearance of the job is neat.

Separate conduits and circuits should be run from the main switchboard direct to distribution cabinets in the mill. Each cabinet should serve a group of motors and in order to make the wiring as short as possible, should be located approximately in the center of the group. This distribution cabinet may be an elaborate slate panel with a fused knife switch for each motor, or it may consist of an asbestos-covered two-inch board backing with externally operated iron-clad fused safety switch mounted on it. The fused switches in the cabinet should be of sufficient size to carry the full starting current of the motor served. The fuses in the distribution cabinet are for protecting the feeder from defective wiring between the motor and cabinet and the motor during starting. For protection of the motor against overload while running, I prefer relays mounted with the starting device. Fuses, unless carefully applied, are an unending source of trouble. The renewable fuse, which has come into wide use during the last few years, can be as reliable as the non-renewable type, but can give all sorts of trouble if the renewals are not put in properly. Loose fitting connections in the fuse itself, in the fuse clips or in the switch will cause heating which is carried to the link causing the fuse to blow with currents far below the capacity of the link. Overloading of switches also causes heating which may be conducted through short connections to the fuses with the same result. Another disadvantage of the fuse is that it does not have an adjustable time characteristic. In many cases of a load with high momentary peaks, it is hard to apply a fuse so that the motor can carry the peaks and at the same time be fully protected from overload, but, a relay can be adjusted to allow overloads of short duration and at the same time protect the motor against overloads of too long duration. Furthermore, when a fuse does blow, the right size replacement is not always used, so that although the first application of fuses was correct, the fusing may be later changed leaving the motor unprotected. For these reasons, I think relays are more satisfactory.

Starting devices of the auto-transformer type should be provided with a low voltage release and be so built that they cannot be left in the starting position. Starters for wound rotor motors should have low voltage release trips on the primary switch and the primary and secondary controls should be interlocked so that the switch be closed only when the controller is in the starting position.

I believe it pays to follow the code of the Fire Insurance Underwriters and Factory Mutuals all the way through the factory both for power and lighting circuits. The lighting system of the sugar factory or any other building should be as carefully designed as any other part of the equipment. With the modern gas filled lamps and industrial reflectors, all ordinary and special lighting requirements can be economically met. Poor lighting has always been a major cause of accidents both to men and machinery in industry. It pays, therefore, to use plenty of light. There are now so many portable electric tools that can be operated from the lighting circuit that it is advisable to place receptacles all over the factory for both portable lamps and tools.

Electrical Equipment of Pump Installations

With the increasing popularity of the centrifugal pump electrical motors are becoming more popular in pumping stations. Wound rotor induction motors are the best suited for pump drives. The centrifugal pumps, for best efficiency must be operated at constant speed, and both the induction motor and the synchronous motor fulfill this condition. The induction motor is easier to start and operate than the synchronous motor and is therefore in most cases preferable. Owing to the large size of motor used, squirrel cage motors are not suitable because of the large starting current taken. In most cases 2300 volts is the best motor voltage to use. Since the pumping plant is usually at some distance from the generating plant with a transmission line intervening it is necessary to use transformers. When transformers are used, the selection of the motor voltage is governed entirely by the cost of the motor and control equipment and the efficiency of the former. Under these conditions, 2300 volts are usually the best.

The control equipment of a wound rotor pump motor should consist of a panel with voltmeter, ammeter, integrating watt-hour meter and overload relays. The oil switch should be provided with low voltage release and trip coils and should be interlocked with the secondary control. For secondary control, either the drum type or the contactor type of controller can be used. If the drum type controller is used, an auxiliary contactor or switch should be provided to short circuit the controller after the motor is brought up to speed.

In cases where power is purchased there is often a penalty for poor power factor. In this case, the use of a synchronous motor may be advisable. An irrigation pumping plant is much more desirable for synchronous motor application than any place in the mill. An irrigation pump is a very steady load and the pumping plants are usually free from dust which causes trouble in machinery having moving contacts.

The control for a synchronous motor should be as simple as possible and yet be complete. The details will depend upon method of starting and control employed by the manufacturer furnishing the motor. Personally, I favor manual rather than automatic control, although I see no reason why the latter should not be very satisfactory.

For driving sump pumps, priming pumps and other small auxiliaries, a single phase motor operating on the lighting voltage will prove satisfactory. For sump pumps, a float switch automatic control works very nicely. The other motors usually will not exceed 5 h.p. and may be controlled by iron-clad safety starting switches.

For the power wiring for the pump motor, I prefer rubber-insulated wire carried on line insulators on racks on the wall and in tunnels to conduit and cable installations. If insulators are used, one need not worry about the detonation of the cable insulation due to heat and moisture.

Electrical Equipment of Generating Plants

The type of electrical equipment for generating depends upon the type of prime mover used. There are for our purposes, three types of prime mover:

turbines, engines and waterwheels, each of which requires a special design of generator although, the electrical design of the last two are about the same. In this paper I will discuss only the alternating current generator as direct current is used but very little on plantations.

Since generator design has been so well developed and standardized, for the different purposes by the builders, there is little to be said about choice of design. When you select the prime mover the generator design is automatically chosen. The main thing to consider is that the machine selected is of good substantial design properly insulated and well ventilated. The turbo alternator is always an enclosed machine with forced ventilation. For turbines it is important that the ventilating system be so designed that all passages and ducts can be readily cleaned. All turbo generators should be equipped with temperature exploring coils connected to a temperature indicator so that the temperatures in the windings can be determined. This is of great value when it is necessary to carry an overload. The engine and waterwheel type generators are open type machines and access can be had to the windings at all times so that temperatures can be observed with an ordinary thermometer.

After the generator the next thing to be considered is the exciter. For turbo generators, I do not favor the direct connected exciter because it is very hard to build commutators and armatures to stand the excessive speed. I think that any plant that is required to operate continuously should have two exciters. My first choice of an exciter is indirection motor driven. This is simplest and most efficient. The second choice is turbine driven. The turbine requires much more attention than an indirection motor and is less efficient, but in the case of central station plant the loss of efficiency may not matter, as the exhaust from the exciter turbine may help maintain the heat balance.

Where a station is not connected to other stations a motor driven exciter cannot be used unless a second steam driven exciter is used for starting up. Even where there are other stations, a steam driven exciter is handy in case of transmission line failure. For these reasons, I favor one motor driven and one steam driven exciter in a turbine driven generating plant. Where there are more than one generator in the plant, the motor driven exciter should have sufficient capacity for all the generators that will be operated at one time. This elminates all difficulties from the parallel operation of exciters especially with the regulator.

For the engine-driven or waterwheel plant, belt-driven exciters are satisfactory; or in case the speed of the main unit is high enough, a direct connected exciter may be used. In large waterwheel plants, an exciter driven by an independent waterwheel may be used, but this would not prove economical in most of the plants found in the Islands. If a spare exciter is required in the engine or waterwheel driven plants a motor driven exciter will prove most satisfactory.

The control equipment of a motor-driven exciter should not be equipped with overload or low voltage protection. In cases of short circuit or other trouble on the outside lines or feeders, it is often found that an overload relay or low voltage trip on the exciter motor control will operate before the oil switch can operate to protect the station from the section on which trouble occurred. When this occurs, the entire load is lost.

Aside from the generator the most important piece of equipment in the station is the switchboard. The switchboard layout varies, depending on the location of the station and the arrangement of lines that it feeds, so cannot well be treated in a general way.

There is one feature that can be spoken of generally and that is, the back of the switchboard should be accessible. Probably the best arrangement is to locate the oil switches and bus bars immediately below the floor upon which the switchboard stands. The generator field rheostats should be mounted above or below the switchboard level. This leaves the back of the board clear and accessible for inspection and work, and there are no dangerous potentials near the board. If it is not practicable to mount the switches below the board, the bus bars and switches should be mounted far enough back of the board so that there is at least six feet between the bus and switch structure and the back of the board. All instrument and control wiring should be run from the bus structure to the switchboard in conduit.

Transmission Systems and Methods of Distribution

The selection of transmission system equipment is largely a question of the purposes to be served. Transmission line design is too large a question to be treated here. To my mind the mechanical design of a transmission is just as important as the choice of electrical equipment. Transmission line equipment consists of four parts from the electrical viewpoint, the line itself consisting of the conductors insulated from the ground, transforming equipment, control equipment and protective equipment. The type, quantity and size of this equipment depends entirely upon the design of the line. Beyond stating that I think that the transmission line is just as important and worthy of careful study as any other portion of the electrical system, I will make no attempt at covering the subject, but leave it for some other report.

The electrical distribution system, except for that in the sugar factory which I have considered above, is always a special problem and cannot be treated briefly in a report of this scope. There are many other phases of the subject of choosing electrical equipment that cannot be gone into but it is hoped that the above covers to some extent the most general features of the subject.

Report on Soils and Fertilizers*

By Guy R. Stewart

The major portion of the work upon the problems of sugar cane soils and fertilization, carried on in Hawaii during the past year, has been done at the Experiment Station, H. S. P. A. The chemical staff of Ewa Plantation, how-

* Presented at Third Annual Meeting of Association of Hawaiian Sugar Technologists, Honolulu, October 27, 1924.

ever, has made a considerable beginning upon a study of the composition of the soils of their fields. This work is intended to supplement the analyses previously made for this plantation by the Experiment Station. The determinations made by the Ewa chemists have so far covered the amounts of strong acid soluble or reserve plant food in a large group of samples. During the present season these figures will be supplemented by the determination of the citrate soluble or available constituents in these same soils. As Ewa Plantation has an extensive group of field experiments which are to be carried on indefinitely, it is an excellent plan to obtain all possible information as to the composition of the experimental fields.

The work carried on at the Experiment Station, H. S. P. A., has been divided again, between work on the soils of the individual plantations, and extended studies of the general problem of the maintenance of fertility in the Island fields. We are steadily gaining information as to the deductions which can be drawn from analyses of plantation soils, by the relationship of our determinations to the yields obtained from field trials. Our major line of investigation of the more general problems of soil fertility, has been the study of the soil conditions underlying the occurrence of root rot or Lahaina disease. This question is still far from being completely solved, but we are obtaining a greater insight into the causes of this trouble than we have ever had before.

Work Upon Plantation Soils

Oahu Sugar Company: A survey of the content of available phosphates in part of the fields of this plantation was made in 1919. The samples were collected largely from the upper fields. A considerable deficiency of available phosphates was found in much of this mauka land. The results of these analyses were in agreement with the plot experiments carried out in Field 45, where a notable response was obtained from phosphate fertilization.

Further interest, in the composition of the Oahu soils, was aroused during the past year by the behavior of H 109 cane in Field 20. A number of poor spots appeared in portions of this field where the cane seemed to be affected by root rot. Soil samples were collected from these poor spots and from adjoining land where good cane was growing. The majority of the samples from both the good and poor areas were low in available phosphates and contained a minimum quantity of available potash. The total potash supply was excellent, but the total phosphates were distinctly low for Island soils.

A definite connection has been shown recently in the Eastern United States, between deficiencies of available phophates and potash and the occurrence of root rot in corn crops. This trouble has been found, usually, on very acid soils where toxic salts of soluble aluminum and iron are present. Such soils are found in these Islands in the mauka lands of the unirrigated plantations. At the same time there is considerable indication that plant food deficiencies may contribute to root troubles in soils that are not notably acid. It seemed desirable, therefore, to make a more general survey of the Oahu Sugar Company lands.

The results of this work showed that most of the areas which were low in available plant food were located in the mauka fields, but that Field 20 was

largely low in phosphate content. Further field experiments with phosphates and potash were recommended. It was concluded that the appearance of root rot in Field 20 was due to a deficiency of plant food and a poor water-holding capacity in the soil of limited areas. The affected cane was given additional fertilization and extra irrigation and has now recovered completely.

Waialua Agricultural Company: A group of samples were analyzed from the various sections of this plantation. A wide range of variation is found in the physical texture and characteristics of the soils found in the Waialua fields. In general, the soils of the lower land were well supplied with both potash and phosphates, while certain of the upper areas were notably low in phosphates. Field experiments were suggested for various sections to develop more exact information as to fertilizer requirements.

Hawaiian Sugar Company: There are a number of ridges and valleys separating the fields, but the soils found in the different sections are rather similar in physical texture. In general, they are reddish, silty, clay loams of good depth, underlain by more compact subsoils at about three feet down.

The analyses of samples from typical areas, appeared to justify the following deductions: A considerable degree of variability was found to exist in the samples from the same fields and from adjoining areas of similar physical appearance. Approximately one third of the samples were found to be low in available phosphates, and almost one half were slightly low in available potash. These results would indicate the desirability of continuing the present applications of phosphoric acid to all the fields. The number of samples containing a minimum quantity of potash would make it desirable to either install potash tests or to add potash to the mixed fertilizers as crop insurance.

Niulii Mill and Plantation: A collection of representative samples from Niulii Plantation were analyzed during the past year. The results showed that about a quarter of the samples were low in available phosphates and about three fourths of the samples were low in available potash. This indicated that most of the plantation cane land was probably giving little return from phosphate applications, but on account of the low areas it was wise to continue moderate phosphate applications. The potash figures indicated a fairly general need of moderate potash applications. These conclusions agree with the results obtained from the field experiments conducted by the Agricultural department.

Hutchinson Sugar Plantation Company: The fields of this plantation were sampled in December, 1923. At this time there was about 3,600 acres in cane. The Manager, Mr. William Campsie, hoped to increase this area to 4,000 or 4,400 acres. In considering this possible expansion, he was anxious to obtain information as to soil and subsoil differences in the various portions of the plantation. The lower fields above Naalehu, and those near Honuapo and Hilea, have been giving excellent yields. Another group of fields in the central section above Naalehu had good crops started upon them, but had been rather uncertain in past production. The very highest fields above Naalehu had been largely out of cultivation for some time.

In general, all the lower fields were found to be well supplied with available plant food. Certain of the central and upper fields above Naalehu were found

to be rather weak in available plant food, but these soils were free from toxic acidity in both the surface and subsoil. Experimental applications of reverted phosphate were recommended for this upper land and deep plowing, on a small scale, was also suggested.

Investigations of the General Properties of Hawaiian Soils

Root Rot Investigations

During the past year our principal investigational problem has been a study of the factors underlying the occurrence of root rot or Lahaina disease. During this time Mr. McGeorge has devoted his entire time to the problem and other members of the Chemistry department have also worked upon the investigation. I think our work has progressed to a point where I am justified in stating that there is every indication that a variety of causes underlay the occurrence of Lahaina disease.

There now seems to be strong evidence that unfavorable soil conditions have been among the determining factors in causing cane to fail through the roots rotting off. In some instances high acidity and consequent toxic quantities of aluminum and iron salts appear to have been among the causative factors. In still other cases seasonal accumulations of salts from irrigating water or an unfavorable alkalinity of the soil, would account for the trouble. It still remains to be shown what the relation of root failure or root rot is to the attacks of soil fungi or soil bacteria; and whether the root injuries caused by snails, centipedes or similar soil inhabitants are a determining factor in such troubles.

The first work undertaken by us was to try and find whether toxic concentrations of aluminum and iron salts would explain the occurrence of root rot here in Hawaii. This work was carried out both in solution and in soil cultures. Great difficulty was experienced in growing cane in solution and sand cultures on account of fermentation and spoilage of the seed piece. Mr. McGeorge finally developed a method by which he obviated this difficulty through the use of the shoots which develop from seed cane. This work has been published in the *Record* for July, 1924, so I shall not give further details of the technique. The general result of these investigations has been to show that salts of aluminum are toxic to cane. These salts were only found in solution in the more acid soils, that is, those with a reaction below pH 5.8. Soils from the upper Hamakua coast and windward Oahu were used in pot cultures and the toxic aluminum was found to be the cause of root failure. This root failure was prevented, in the pot tests, by heavy applications of superphosphate or by partial neutralization of the soil with lime and the use of moderate amounts of superphosphate. Field tests have now been installed at Honokaa, Olaa and Grove Farm to try out these methods of treatment on acid soils under field conditions.

Later work was undertaken to try and find the cause of the failure of Lahaina upon the neutral soils of the irrigated plantations. One of the causes of such failure appears to be seasonal accumulations of salts from the irrigating water. This work has been discussed in detail in the *Record* for July, 1924. Another cause of root failure was found by work at Oahu Sugar Company to be a

deficiency of available plant food. In this instance it was available phosphates. Still another instance of root failure was investigated in central Maui at the Hawaiian Commercial and Sugar Company. An unfavorable degree of alkalinity was found in the preliminary work, but further study is still to be carried out in this district.

During the present summer Mr. McGeorge has visited the prominent investigators of root rot problems in the Eastern United States and has become thoroughly conversant with the work which they have under way. He conferred with the investigators at Indiana, New Jersey, Rhode Island, Wisconsin and the U. S. Department of Agriculture at Washington, D. C.

Preliminary Work on Pahala Blight

During the past winter there was considerable Pahala blight in certain fields of the Hawaiian Agricultural Company. Mr. McGeorge visited Pahala in January of this year, took soil samples of typical blight and non-blighted fields and also collected samples of blighted and normal leaves. Besides collecting the above samples, he obtained some large lots of soil and later displaced the soil solutions and used these solutions for the growth of cane shoots.

Analyses of the soils indicated that the blight soils had a more shallow surface soil with a marked decrease of available plant food in the subsoils. The analyses of the cane leaves showed that the blight-free leaves had a higher ash and silica content than those affected by blight. An increased absorption of silica is generally affected by a satisfactory content of available phosphates, so this also points to a lack of available plant food as one of the causes of the trouble.

The growth of cane shoots in soil solutions from the blight and non-blight soils showed a notably better growth in the solutions from the blight-free soils. The analyses of the solutions did not show a consistent difference which would account for this difference in growth.

We have since made a fairly complete soil survey of the fields of Hawaiian Agricultural Company to find if there are consistent differences in the soils of all the blight and blight-free fields. Work is now under way upon these samples. This will be followed by further work on the composition of the cane when blight is present and a continuation of the cultural experiments.

Sugar Prices

96° Centrifugals for the Period

Dec. 17, 1924, to March 11, 1925

Date	Per Pound	Per Ton	Remarks
Dec. 17, 1924	4.77¢	$95.40	Cubas.
" 22	4.74	94.80	Cubas, 4.77, 4.71.
" 23	4.71	94.20	Cubas, 4.77, 4.65; Philippines, 4.71.
" 26	4.65	93.00	Cubas.
" 27	4.59	91.80	Cubas.
Jan. 2, 1925	4.65	93.00	Cubas.
" 6	4.59	91.80	Cubas.
" 8	4.55	91.00	Porto Ricos.
" 9	4.535	90.70	Cubas, 4.55, 4.52.
" 10	4.59	91.80	Cubas.
" 13	4.535	90.70	Cubas, 4.55; Porto Ricos, 4.52.
" 14	4.55	91.00	Porto Ricos.
" 16	4.57	91.40	Cubas, 4.55, 4.59.
" 17	4.59	91.80	Cubas.
" 19	4.62	92.40	Cubas, 4.62, 4.65; Porto Ricos, 4.59.
" 20	4.65	93.00	Cubas.
" 21	4.62	92.40	Cubas, 4.65; Porto Ricos, 4.59.
" 22	4.59	91.80	Cubas.
" 23	4.535	90.70	Cubas, 4.52, 4.55.
" 24	4.52	90.40	Porto Ricos.
" 26	4.59	91.80	Cubas.
" 29	4.65	93.00	Cubas.
" 30	4.635	92.70	Cubas, 4.65, 4.62.
" 31	4.635	92.70	Cubas.
Feb. 2	4.65	93.00	Cubas.
" 4	4.59	91.80	Cubas.
" 9	4.62	92.40	Porto Ricos, 4.59; Cubas, 4.65.
" 11	4.59	91.80	Cubas.
" 17	4.62	92.40	Cubas.
" 18	4.605	92.10	Cubas, 4.62; Porto Ricos, 4.59.
" 19	4.59	91.80	Cubas.
" 25	4.65	93.00	Cubas.
" 26	4.725	94.50	Cubas, 4.71; Porto Ricos, 4.74.
" 27	4.755	95.10	Cubas, 4.77, 4.74.
" 28	4.74	94.80	Cubas.
Mar. 3	4.725	94.50	Cubas, 4.74, 4.71.
" 4	4.71	94.20	Cubas.
" 5	4.74	94.80	Cubas.
" 6	4.755	95.10	Cubas, 4.74, 4.77.
" 7	4.84	96.80	Cubas.
" 9	4.825	96.50	Cubas, 4.84; Porto Ricos, 4.81.
" 10	4.79	95.80	Cubas, 4.81, 4.77.
" 11	4.77	95.40	Cubas.